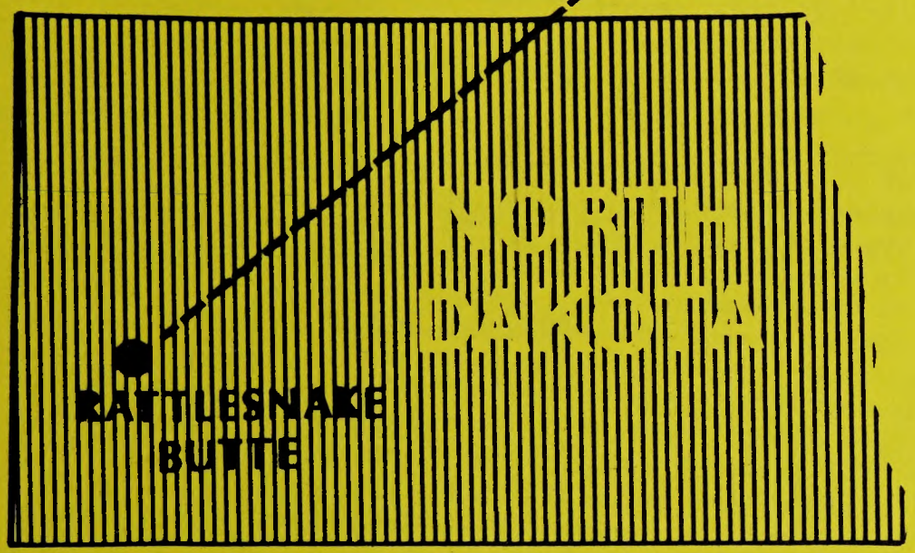
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Rattlesnake Butte Study Area Report



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Rattlesnake Butte Study Area Report
Published June, 1982

The Federal Coal Management Program has been designed as an interagency cooperative effort to meet national energy objectives.

Rattlesnake Butte Study Area Report was prepared through the efforts of the U.S. Department of the Interior, principally the Bureau of Land Management, Geological Survey, and Bureau of Reclamation.* The study effort began in 1978 and was concluded in 1982 with the publication of this report.

The area described in this report has been tentatively determined to be a potential Federal coal development area. The purpose of this report is to provide information on the area's reclamation potential, should coal development occur. This report will assist managers in making final Federal coal leasing decisions.

Limited copies of this report are available from:

Bureau of Land Management
Montana State Office
222 N. 32nd Street
Billings, MT 59107

Please reference the title and report numer 22-78 when making a request for this report from the Bureau of Land Management.

Other reports available through Technical Investigations in Support of the Federal Coal Management Program are:

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Henry Mountain, UT	15-77	Chromo/4, MT	46-75
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Kimbeto, NM	17-77	Dam Creek, MT	48-77
Ojo Encino, NM	19-78	Shy/6, MT	49-78
		Newell/28, MT	50-78

For more information on these reports, contact:

Bureau of Land Management
DFC, Bldg. 50, D-450
Denver, CO 80225
303-234-2374

*In May of 1981, the Secretary of the Interior approved changing the Water and Power Resources Service back to its former name, the Bureau of Reclamation. All references in this publication to the Water and Power Resources Service should be considered synonomous with the Bureau of Reclamation.

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Prepared jointly by Bureau of Land Management, Bureau of Reclamation, and Geological Survey.

16. Abstract The purpose of this investigation was to collect baseline data for establishing reclamation objectives and lease stipulations. The report includes data on climate, physiography, geology, coal resources, and overburden. The study area, located in Southwestern North Dakota, lies within the unglaciated portion of the Great Plains Physiographic Province. Climatic conditions are characterized by cold winters, warm summers, and large variations in seasonal precipitation. Average annual precipitation is 15.5 inches; the frost-free season averages 122 days. Bedrock exposed along deeply-incised drainages and in the uplands is the Sentinel Butte Member of the Paleocene Fort Union Formation. Surface-minable resources in three lignite beds, which range in thickness from 1.4 to 18 feet, total 484 million tons. Of this, 128 million tons is in beds more than 10 feet thick under less than 200 feet of overburden. Coal rank is Lignite A to B. Most soils in the study area should yield 6 to 12 inches of topsoil which is non-saline, nonsodic, and permeable. Available subsoil materials appear fair to poor in quality due to high salinity, sodicity, and/or clay content. Only 3 percent of the bedrock samples from 15 USBR drill holes were rated suitable for use as supplemental plant media; 7 percent were of limited suitability; and 90 percent were unsuitable. Excessive exhangeable sodium was the major limiting factor. Based on the resource data in this report, the potential for restoring surface-mined land in this study area to a condition capable of supporting the present uses (rangeland, hayland, cropland) appears good.

17. Document Analysis a. Descriptors
0510 Environmental Surveys
0807 Coal Deposits
1407 Reclamation

b. Identifiers/Open-Ended Terms
North Dakota, surface-mined land, reclamation potential, soils, vegetation, geology, geomorphology, hydrology, climate

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
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RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD
NORTH DAKOTA

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RESOURCE AND POTENTIAL RECLAMATION EVALUATION OF RATTLESNAKE BUTTE STUDY AREA DICKINSON COALFIELD NORTH DAKOTA

INTRODUCTION

Recent energy shortages have forced our society to seek new domestic sources. Attention has focused on the immense quantities of low sulfur coal that lie within the Rocky Mountain and Northern Great Plains regions. It is the responsibility of the Department of the Interior and, principally, the Bureau of Land Management to assist in meeting these energy demands and, at the same time, provide sound reclamation guidelines so that the disturbed lands are restored to an acceptable condition.

PURPOSE

The purpose of this report is to provide information for establishing reclamation objectives and lease requirements. Detailed data is given on geology, coal resources, and overburden (soil and bedrock). Less detailed information is provided on climate and physiography.

REPORT OBJECTIVES

1. To analyze and quantify the environmental impacts from surface mining of coal.

2. To provide resource and impact information for leasing site selection procedures as set forth by the Secretary of the Interior.

3. To provide environmental resource information needed to implement effective reclamation and rehabilitation programs and for the development of meaningful lease stipulations as required by the mined land reclamation program.

4. To provide resource and impact information to support State and local regional development and land use planning efforts.

5. To determine the present and potential capability of the soil and bedrock to support and maintain vegetation on known coal deposits.

6. To provide physical and chemical data from which realistic stipulations may be provided for exploration, mining, and reclamation plans.

7. To provide data needed in the preparation of Environmental Impact Statements, Environmental Analysis Records, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the study area.

AUTHORITY

Federal Land Policy and Management Act of 1976 and Surface Mining Control and Reclamation Act of 1977.

RESPONSIBILITY

BUREAU OF LAND MANAGEMENT

1. Selects study area for coordinated investigations of climate, geology, overburden, and coal resources.

2. Acts as Contracting Officer in the coordination, establishment and execution of work orders.

3. Procures easements and rights-of-way to conduct the studies.

4. Distributes technical data, reports, and reclamation and rehabilitation recommendations to Bureau of Land Management field offices.

5. Determines postmining land uses.

BUREAU OF RECLAMATION

1. Conducts a land classification for determining suitability of soil/bedrock material within 10 feet of the surface for use in revegetation of the disturbed area.

2. Conducts drilling operations for the procurement of core samples for coal and overburden analysis.

3. Characterizes and interprets suitability of overburden material as well as substrata immediately below the coal resources for purposes of revegetation.

4. Conducts mechanical weathering tests of core samples to determine stability of overburden materials.

5. Recommends to District Office, Bureau of Land Management, suitable plant species for use in areas to be reclaimed.

6. Advises District Office, Bureau of Land Management, on reclamation techniques.

7. Prepares geologic maps, logs, and cross sections.

8. Advises the Bureau of Land Management on paleontological finds in the study area.

9. Coordinates assembly and printing of final report.

U.S. GEOLOGICAL SURVEY

1. Investigates coal resources.

GENERAL DESCRIPTION

LOCATION

The Rattlesnake Butte Study Area is located in southwestern North Dakota in parts of Stark, Billings, and Dunn Counties. Plate 1 shows the general location. The study area includes approximately 13,070 acres in all or parts of sections 2, 4, 6, 8, 10, 14, 18, 20, 22, 26, 28, 30, 32, and 34, T. 140 N., R. 98 W.; sections 2, 10, 12, 14, 22, 24, 26, 30, and 34, T. 140 N., R. 99 W.; section 32, T. 141N., R. 97 W.; and sections 32 and 34, T. 141 N., R. 98 W. The USBR land classification study was expanded to include about 2,250 additional acres along the north edge of the study area in all or parts of section 30, T. 141 N., R. 97 W., and sections 26, 28, and 30, T. 141 N., R. 98 W. Photograph 1 shows the complete study area including the additional sections covered by the land classification study. Plate 2 shows the area topography. All surface is privately owned. All coal is federally owned as shown on Plate 3.

PRESENT LAND USES

Most of the land within the Rattlesnake Butte Study Area is used for small grain farming, cattle grazing and hay production.

The area is not forested except for some scrubby growth along a few drainages. Little except firewood or maybe fence posts could be produced from the few trees that exist. This riparian vegetation does, however, provide extremely valuable wildlife habitat that is particularly essential for winter survival.

Two coal mines and numerous scoria pits are located in the study area, but they are small in size and inactive. Specific locations are shown on the topographic map, Plate 2.

Although the area is not being specifically managed for watershed protection, this indirect use should also be recognized.

POSTMINING LAND USES

Postmining land uses in the study area are expected to be the same as the present uses. These uses are rangeland, hayland, and cropland (small grains, corn, sunflowers).

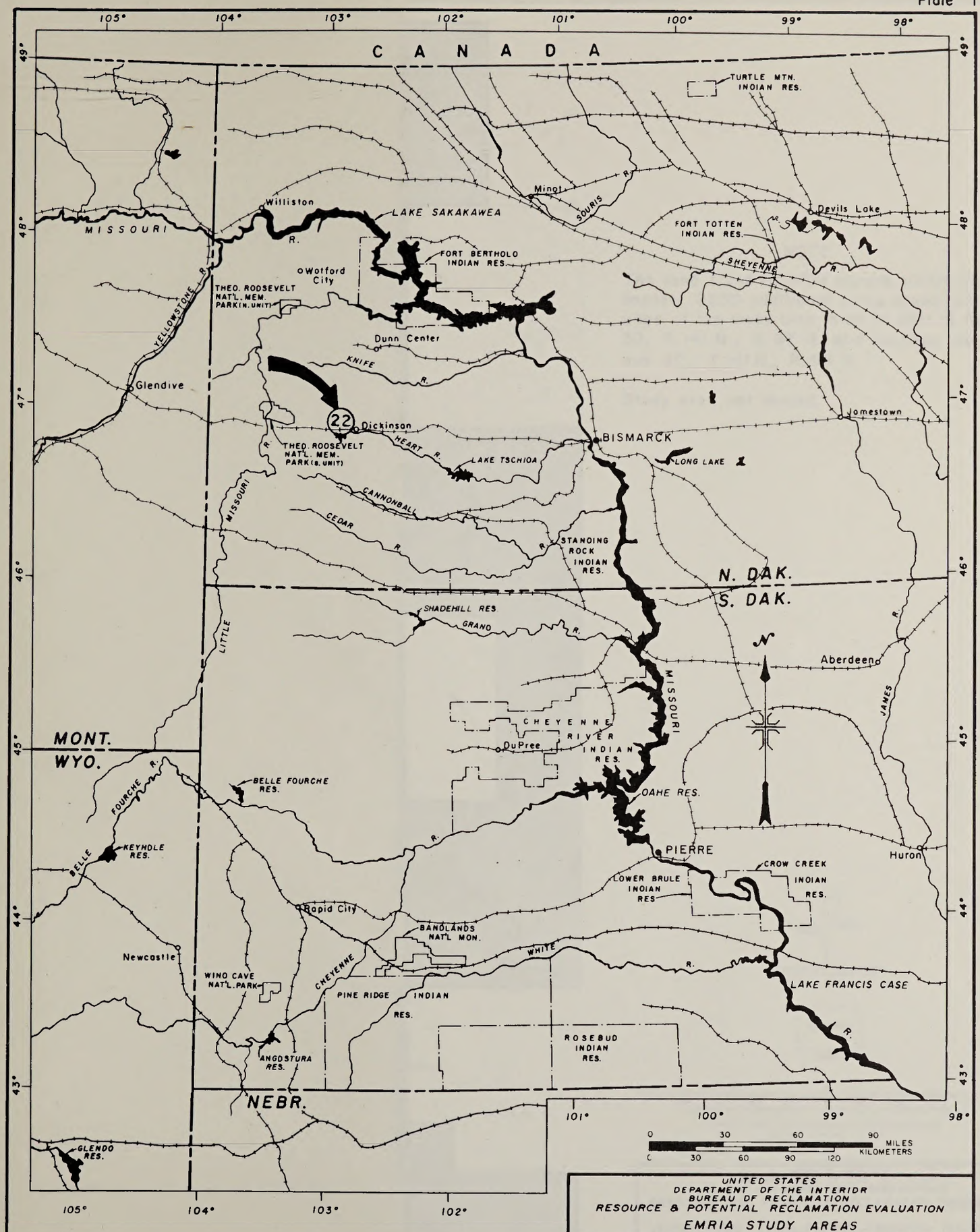
RULES GOVERNING MINING AND RECLAMATION OPERATIONS

In North Dakota, coal mine operators must comply with all established rules and regulations pursuant to the North Dakota Surface Mine Reclamation Act, 1979 (Chapter 38-14.1 of the North Dakota Century Code). These rules and regulations are presented in Appendix B of the North Dakota State Program for regulating surface mining and reclamation activities.[1/]

The North Dakota Public Service Commission is the regulatory agency responsible for administering this program.

1/ The North Dakota State Program was published March 3, 1980. Conditional approval of this program was granted by the U.S. Department of the Interior, Office of Surface Mining, on December 15, 1980.

Plate I



(22) RATTLESNAKE BUTTE STUDY AREA - EMRIA No. 22

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

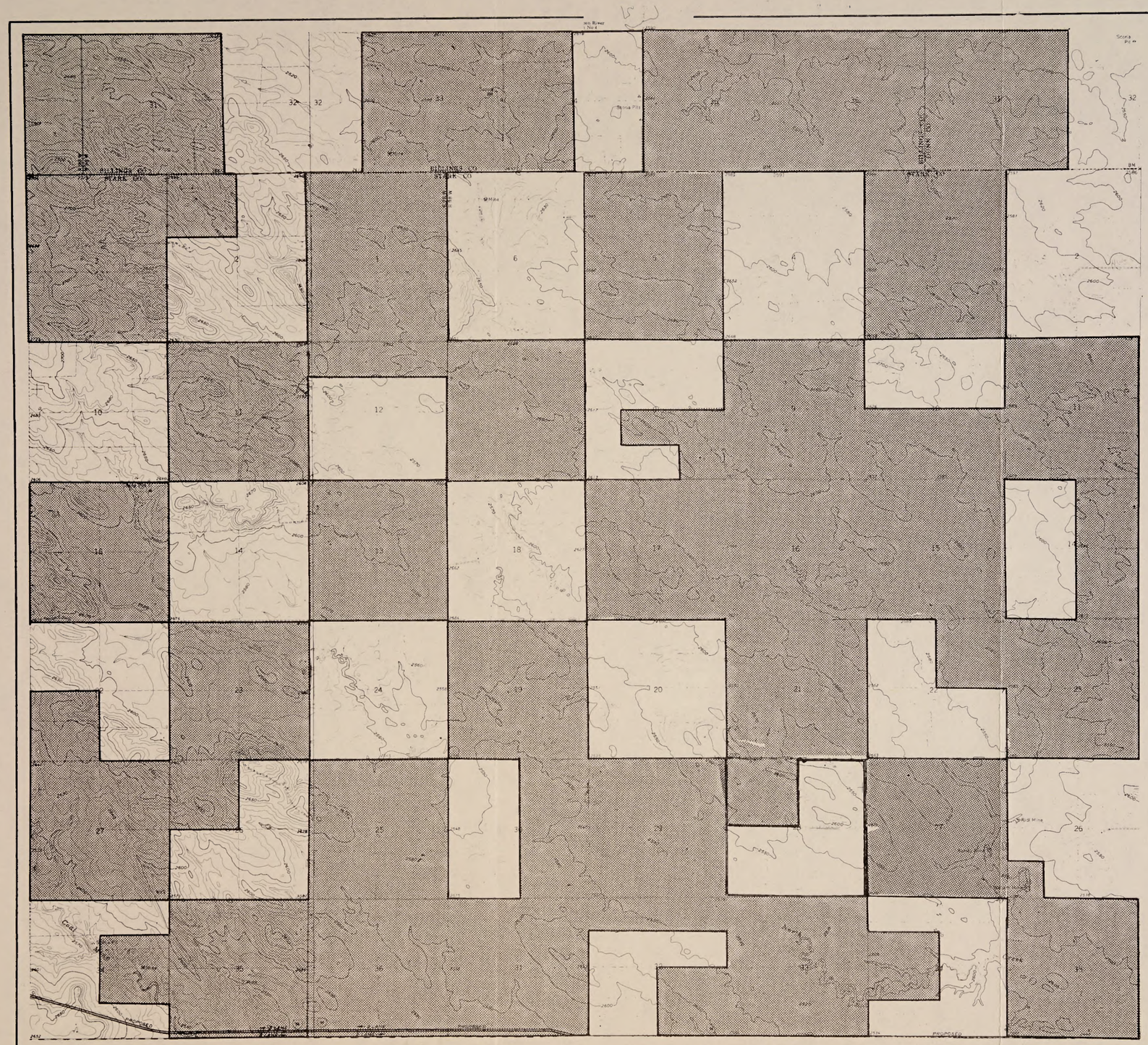
EMRIA STUDY AREAS
NORTH DAKOTA, SOUTH DAKOTA, MONTANA & WYOMING

GENERAL LOCATION MAP

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DRAWN V. LINDSEN RECOMMENDED
CHECKED E.J.T. APPROVED

BILLINGS, MONTANA MARCH 1976 | 1305-600-244

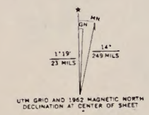




NOTE

The land classification survey covers approximately 2250 additional acres along the north edge of the study area in all or part of Section 30, T. 141 N., R. 97 W., and sections 26, 28, and 30, T. 141 N., R. 98 W.

Study area not shaded.



UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD – NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA
TOPOGRAPHY

DESIGNED L. PARISH	FIELD APPROVAL
DRAWN L.E. ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED
BILLINGS, MONTANA	MARCH, 1980

1305-600-245



MINERALS OWNED BY THE FEDERAL GOVERNMENT

COAL ONLY

OTHER

NOTES

All surface privately owned except the N ½ of Section 36, T. 141 N., R. 98 W. It is state owned.

Data from BLM Surface-Minerals Management Quad. SW-2

The land classification survey covers approximately 2250 additional acres along the north edge of the study area in all or parts of Sec-30, T. 141 N., R. 97 W., and Sections 26, 28, and 30, T. 141 N., R. 98 W. The surface is privately owned but the coal is federally owned.

1°19' 23 MILS

14° 249 MILS

UTM GRID AND 1982 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

NORTH DAKOTA

LOCATION

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 MILE

1 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA
MINERAL STATUS MAP

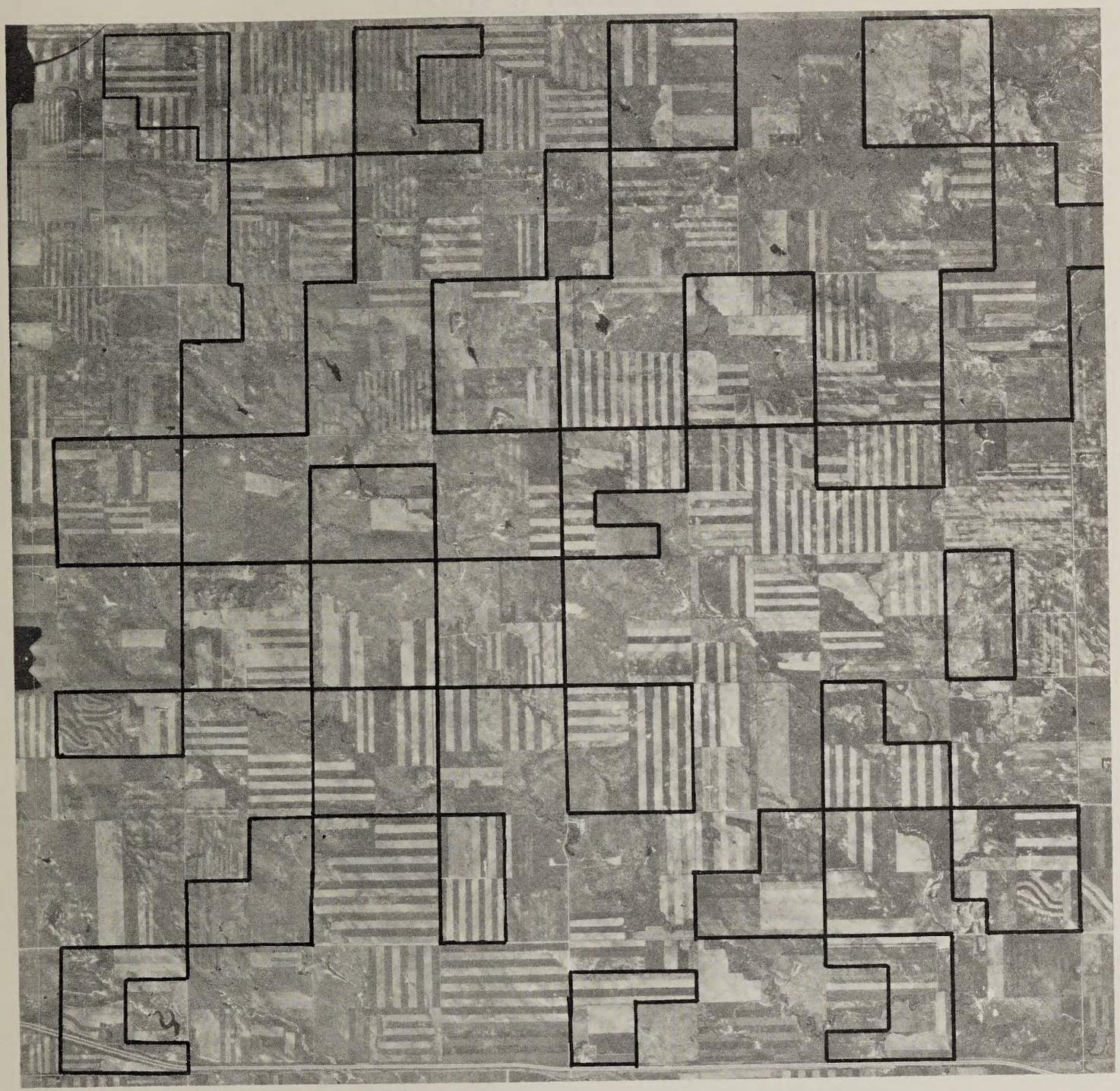
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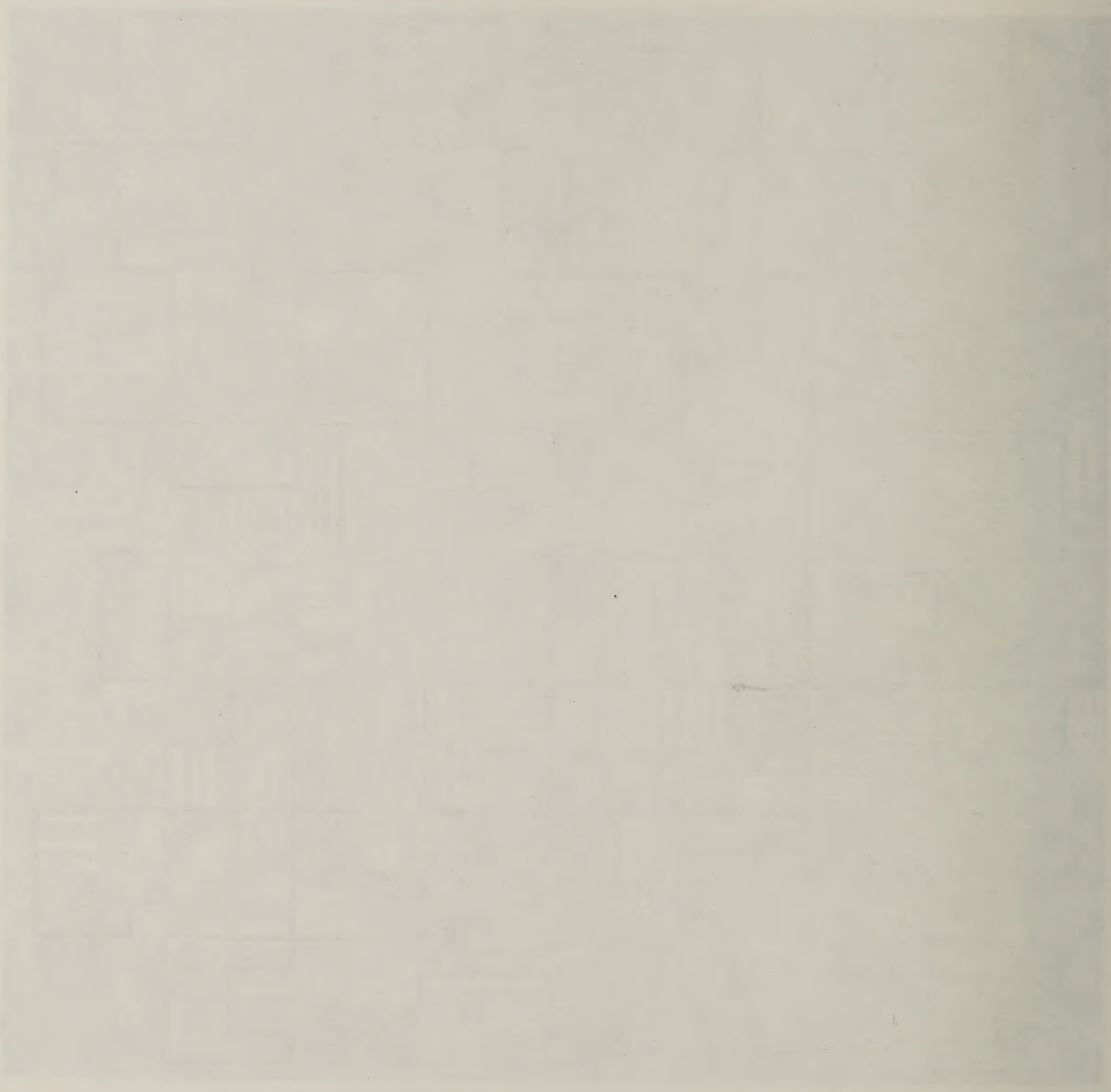
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Photograph 1 - Aerial view of the Rattlesnake Butte Study Area. This photograph is a portion of the Bureau of Land Management Surface-Minerals Management Quad. SW-2.



OBJECTIVE OF RECLAMATION

North Dakota law presently requires the coal mine operator to "restore the land affected to a condition capable of supporting the uses which it was capable of supporting prior to any mining, or higher or better uses approved by the (Public Service) Commission. . ./Chapter 38-14.1-24(2) of the North Dakota Century Code--North Dakota Surface Mine Reclamation Act, 1979/. Alternative postmining land uses may be approved by the Public Service Commision after consultation with the landowner.

Unless an alternative postmining land use is desired by the landowner(s) and approved by the Public Service Commission, the main objective of reclamation in the Rattlesnake Butte Study Area will be to restore the disturbed land to a condition capable of supporting the uses that it supports at the present time. These uses are rangeland, hayland, and cropland (small grains, sunflowers, corn).

PHYSICAL PROFILE

CLIMATE [1/]

The Rattlesnake Butte Study Area has a continental-type semiarid climate characterized by harsh, cold winters, warm summers, and large variations in seasonal precipitation.

Precipitation

The mountains along the Continental Divide cause air masses to rise and precipitate their moisture, primarily on the windward slopes. The air masses then warm and dry as they descend the leeward slopes. As a result, a semiarid condition is created in much of eastern Montana and western North Dakota.

Table 1 is a listing of mean monthly and annual precipitation values recorded at Dickinson, North Dakota (about 20 miles east of the study area).

Wide deviations from the mean annual precipitation value have been recorded in this area, with as little as 7 inches and as much as 31 inches being received. More than 75 percent of the annual precipitation occurs during the growing season, April through September. As much as 10 inches may fall in June, which is commonly the wettest month. Most of the precipitation falls during thunderstorms.

Snowfall is most common between October and late April. However, small amounts may occur in September and May. The amount of snow received annually ranges widely from 12 to about 74 inches, but the yearly average is approximately 32 inches. Only about 12 percent of the annual precipitation occurs during the period of November through February; nevertheless, a measurable amount of snow can be expected in the months of November through April.

Temperature

Based on data recorded at Dickinson, North Dakota, temperature extremes of 101°F in summer and -32°F in winter are probable (2 years in 10) in this area.

Generally, about 22 days each year have a maximum temperature over 90°F, but a maximum temperature exceeding 100°F occurs only 2 to 3 days a year, and in some years not at all. In an average year, about 46 days have a minimum temperature of 0°F of lower.

Average daily maximum and minumum temperatures recorded at Dickinson, North Dakota, are listed in Table 2.

1/ Data in this section was obtained from: Soil Survey of Stark County, North Dakota; Soil Conservation Service, 1968

Table 1 - Mean Monthly and Annual Precipitation Values (Inches)
Rattlesnake Butte Study Area*

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
.44	.44	.74	1.24	2.20	3.50	2.17	1.78	1.19	.85	.55	.40	15.5

Table 2 - Average Daily Maximum and Minimum Temperatures
Rattlesnake Butte Study Area*

Average Daily Maximum Temperature (^{o}F)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
23	25	26	55	66	75	84	82	71	58	40	28	54

Average Daily Minimum Temperature (^{o}F)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1	2	14	28	39	49	54	52	41	31	18	6	28

*Data from Dickinson, North Dakota, recording station.

The average length of the frost-free (>32°F) growing season in this area is 122 days. This value is based on data recorded at Dickinson, which indicates that the average date of the last temperature of 32°F or lower in spring is May 20, and the average date of the first temperature of 32°F or lower in fall is September 19. The growth of native range plants is rapid in this area during May and June. However, by mid-July, the available soil moisture is usually depleted and the plants mature or become dormant.

Other Climatic Factors

On the average, thunderstorms occur on 30 to 35 days each year, and hail generally falls on 2 or 3 of these days. Hailstorms are most common between May and August. However, hail may also occur infrequently in March, April, September, and October. Damage to crops from hail may be severe in this area (Stark County ranks fifth in the State of North Dakota in the amount of insured acreage on which crops have been reported damaged).

Winds that erode unprotected soils occur 34 percent of the time, primarily during April, May, and June. Between May and July, winds generally blow from the southeast, whereas the period of September through May shows the winds blowing primarily from the northwest. Winds from the west and south occur throughout the year. Wind speeds of greater than 47 miles per hour have not been recorded in this area.

This area receives approximately 60 percent of the sunshine that could possibly occur each year.

Effect of Climate on Revegetation

Most climatic factors in the Rattlesnake Butte Study Area appear favorable for revegetation of surface-mined land with native range plants, small grains, or other adaptable crops. However, several hazardous climatic factors which may adversely affect revegetation efforts in the area should be recognized. These are: (1) below normal or uneven distribution of precipitation, especially during the growing season, (2) severe thunderstorms or hailstorms that cause crop damage and soil erosion, (3) late spring freezes, and (4) soil erosion and moisture depletion by wind.

Spring is the most favorable planting time in this area since soil moisture is generally high during the early part of the growing season. The spring rains usually provide moisture to the soil in excess of the plant moisture requirement. With favorable soil moisture and temperature conditions, spring-planted grasses should germinate rapidly and become established before the available soil moisture is depleted in mid-July.

PHYSIOGRAPHY

The Rattlesnake Butte Study Area lies in the unglaciated Missouri Plateau section of the Great Plains Physiographic Province. This section is characterized by a series of complex, narrow divides which are the eroded remnants of a once widely extensive plateau.

The topography of this study area is variable, ranging from nearly level and gently sloping stream terraces, fans, and footslopes to steep, rolling uplands. Sedimentary strata of the Fort Union Formation (Sentinel Butte Member) are exposed along deeply-incised drainage channels and, to a lesser extent, at higher elevations in the uplands. Wind-worked sandy deposits are also notable at higher elevations in the uplands. Resistant scoria (baked shale) outcrops are common throughout this study area. These outcrops appear as thin, remnant "caps" over gentle and moderately sloping uplands.

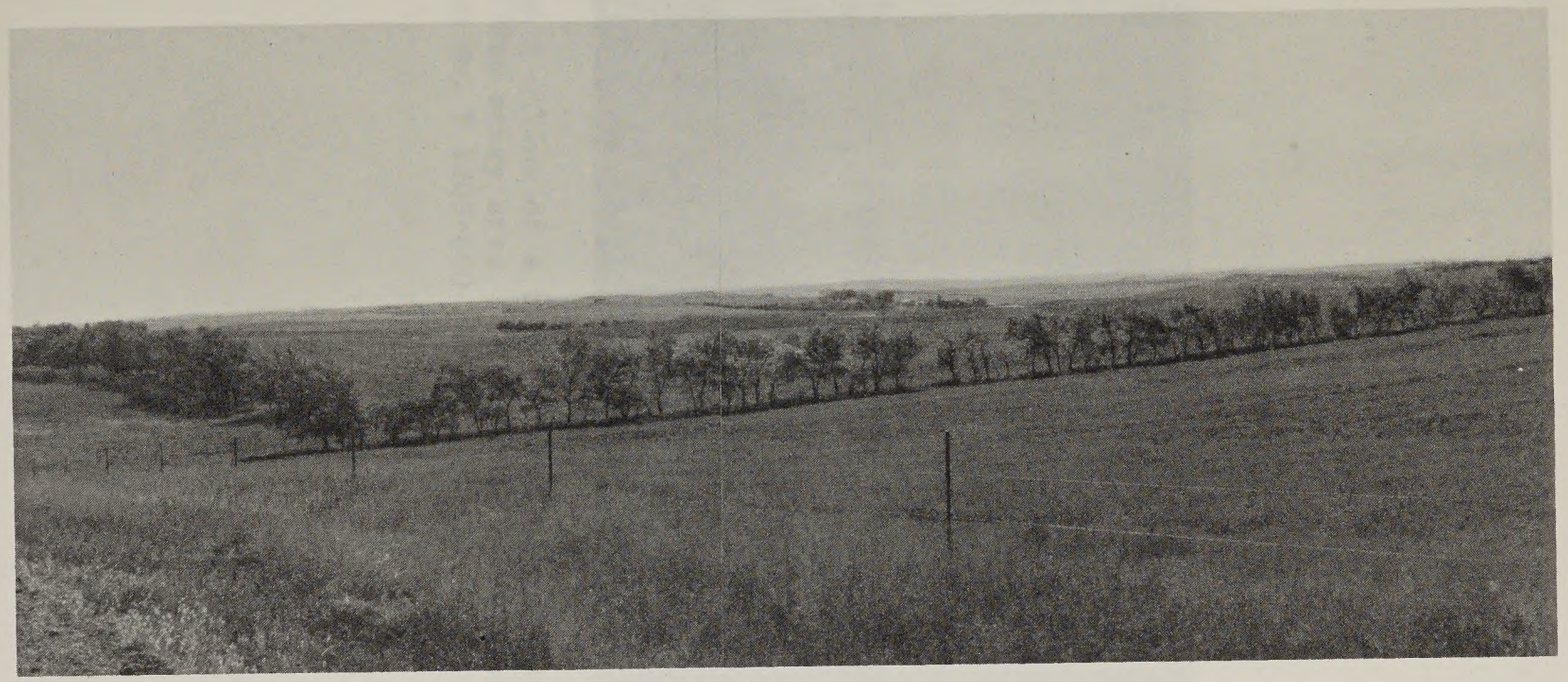
The relief in this study area is approximately 260 feet, ranging from 2470 feet along North Creek in the southeast corner of the study area to 2730 feet in the uplands.

Drainage of the study area is accomplished through an extensive network of branching drainages (dendritic pattern). The majority of the area drains southeastward to the Heart River via North Creek and its tributaries. The northern portion of the study area drains in a northwesterly direction toward Green River.

Photographs 2 through 5 are typical views of topography within the Rattlesnake Butte Study Area.

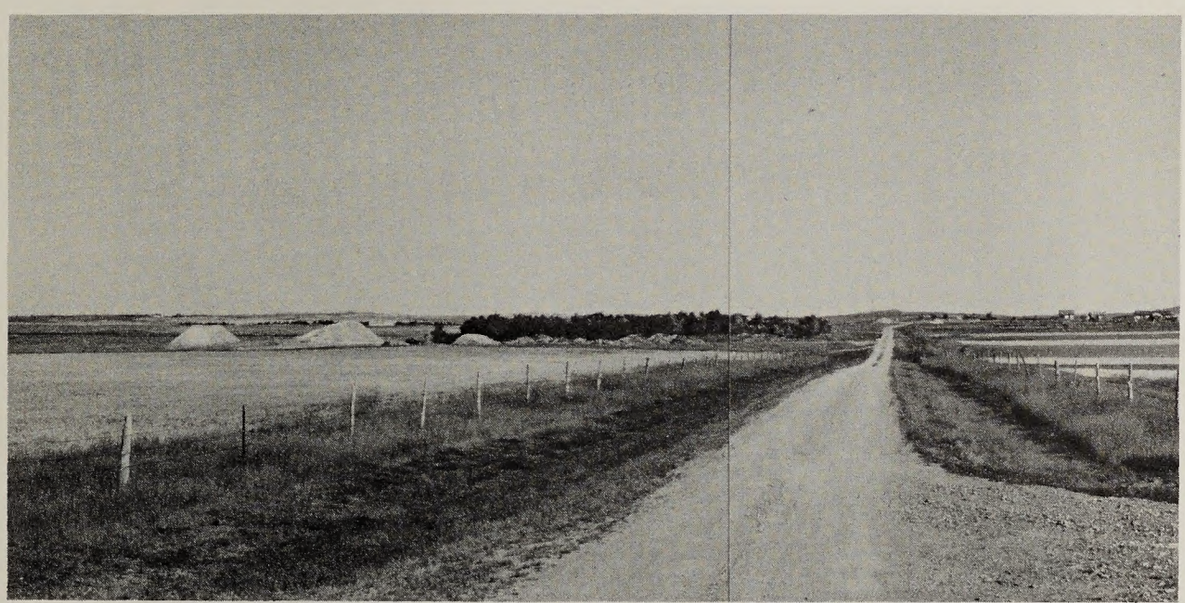


Photograph 2 - View looking northwest from near the northeast corner of section 14, T. 140 N., R. 97 W. Water and Power Resources Photograph No. P 1305-600-26, 9/79.



Photograph 3 - View of the study area looking southeast from near the northwest corner of section 3, T. 140 N., R. 99 W. Water and Power Resources Service Photograph No. P 1305-600-27, 9/79.





Photograph 4 - View of a typical scoria pit near the northeast border of the study area. Water and Power Resources Service Photograph No. P 1305-600-28, 9/79.





Photograph 5 - View of the study area looking southwest from near the northwest corner of section 35, T. 140 N., R. 99 W. Water and Power Resources Service Photograph No. P 1305-600-29, 9/79.

GEOLOGY

Regional Geology

The Dickinson Coalfield is located in the Williston Basin in west-central North Dakota. This basin, a part of the Great Plains Physiographic Province, is a synclinal structure extending from South Dakota into Canada, a distance of about 500 miles.

The geologic history of the area since Precambrian time includes periods of deposition, deformation, and erosion. A sequence of carbonates, sandstones, and shales, mostly of marine origin, were deposited throughout North Dakota during the Paleozoic and Mesozoic Eras. These sediments, about 14,000 feet thick in the deepest part of the Williston Basin, thin rapidly eastward and are not present in the southeastern part of the State. Several unconformities exist throughout the Paleozoic and Mesozoic sequences in North Dakota, the most notable being the pre-Mesozoic erosional surface which truncates all Paleozoic sediments.

Deformation of the Rocky Mountains to the west and associated uplifting of the Great Plains area in North Dakota began with the Laramide Revolution at the close of Cretaceous time. Intermittent uplifting continued through the Paleocene and ended in Eocene time. Materials eroded from the mountains were spread in thick sheets over most of the Great Plains by the middle of the Cenozoic Period. A second regional uplift which occurred during Pliocene and Pleistocene times elevated sediments to their present position. Streams rejuvenated by the uplift began stripping Tertiary strata from the Great Plains and exhuming the buried mountain masses to the west.

During the Pleistocene Epoch, several continental ice sheets invaded most of North Dakota. A sequence of till, outwash, and associated glacial debris was deposited during the advance and retreat of each ice sheet.

Today, shales, siltstones, and sandstones of Cretaceous and Tertiary age cover the western part of North Dakota. Pleistocene and Holocene glacial, eolian, and alluvial deposits mantle the bedrock in much of the area. Plate 4 is generalized regional geologic map showing the southern limits of glaciation.

Area Geology

Investigations

Surface and subsurface investigations were conducted by the Bureau of Reclamation at the Rattlesnake Butte Study Area during January and February 1978 and January through April 1979. These investigations included mapping the surface goelogy and drilling a series of core holes.

Geologic mapping was done in the field on aerial photographs. The data was transferred to a topographic map and is shown on Plate 5. Plate 6 is a

stratigraphic column describing lignite beds shown on Plate 5. Fifteen drill holes (DH78-101 and DH78-102 and DH79-103 through DH79-115) ranging from 120.0 to 245.6 feet in depth were completed in the study area. Continuous cores were obtained from all holes for geologic logging and selection of coal and overburden samples for laboratory analyses. The locations of drill holes are plotted on the Geologic Investigations Map, Plate 5. Plates 7 through 11 are geologic profiles correlating lignite horizons between drill holes. Detailed geologic logs are shown on Plates 12 through 26, Appendix B.

Drilling was performed with rotary drills using wire line tools with an "H" series core barrel. Except for drive sampling in overlying residual material with a Bx casing drive barrel, all drilling was done using bottom discharge core bits set with tungsten carbide inserts.

Water was used as drill fluid in all holes. An organic polymer, "Revert," was used in the drilling fluid in fractured or jointed rock where circulation was lost.

The drill core was immediately placed in core boxes and wrapped with plastic to prevent drying until it could be logged and sampled.

After completion, all drill holes in the study area were backfilled with concrete.

Stratigraphy

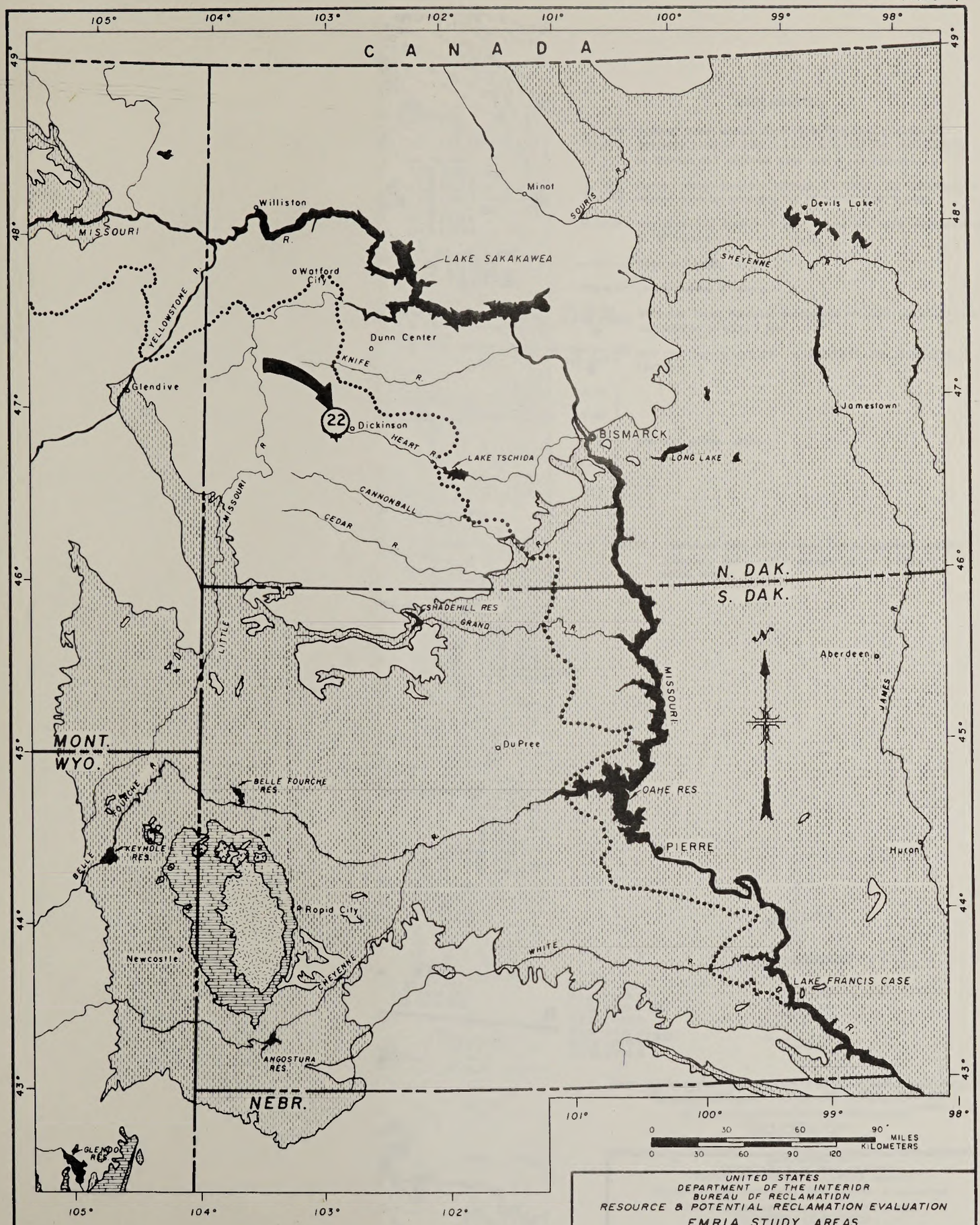
The oldest rocks exposed in the study area are of Paleocene Age. In North Dakota, the U.S. Geological Survey has divided the Paleocene Series into the Ludlow-Cannonball, Tongue River, and Sentinel Butte Members of the Fort Union Formation. These subdivisions will be used in this section of the report. Only the Sentinel Butte, the youngest member of the Fort Union Formation, is involved in the study area. Sandstones, siltstones, and shales of this member are locally mantled by slopewash and alluvium.

Fort Union Formation - Paleocene

Cannonball-Ludlow Member - These sediments underlie but do not crop out in the study area. The Cannonball is the youngest known marine strata in the Northern Great Plains region. It consists of shale and thin-bedded sandstone which thins and interfingers westward with the continental deposited Ludlow.

Tongue River Member - consists of an alternating sequence of fluvial deposited sandstone, siltstone, and shale with associated beds of lignite. It is similar to the overlying Sentinel Butte Member, and in places, cannot be distinguished from it. It also does not crop out in the study area.

Sentinel Butte Member - consists of an alternating sequence of sandstone, siltstone, shale, carbonaceous shale, and lignite with thin calcareous



CENOZOIC

CENOZOIC (IGNEOUS)

MESOZOIC

PALEOZOIC

PRECAMBRIAN

SOUTHERN LIMITS OF GLACIATION

22 RATTLESNAKE BUTTE STUDY AREA - EMRIA No.22

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

EMRIA STUDY AREAS
NORTH DAKOTA, SOUTH DAKOTA, MONTANA & WYOMING

GENERALIZED REGIONAL GEOLOGIC MAP

DESIGNED V. LINSSEN G. TAUCHER SUBMITTED

DRAWN V. LINSSEN RECOMMENDED

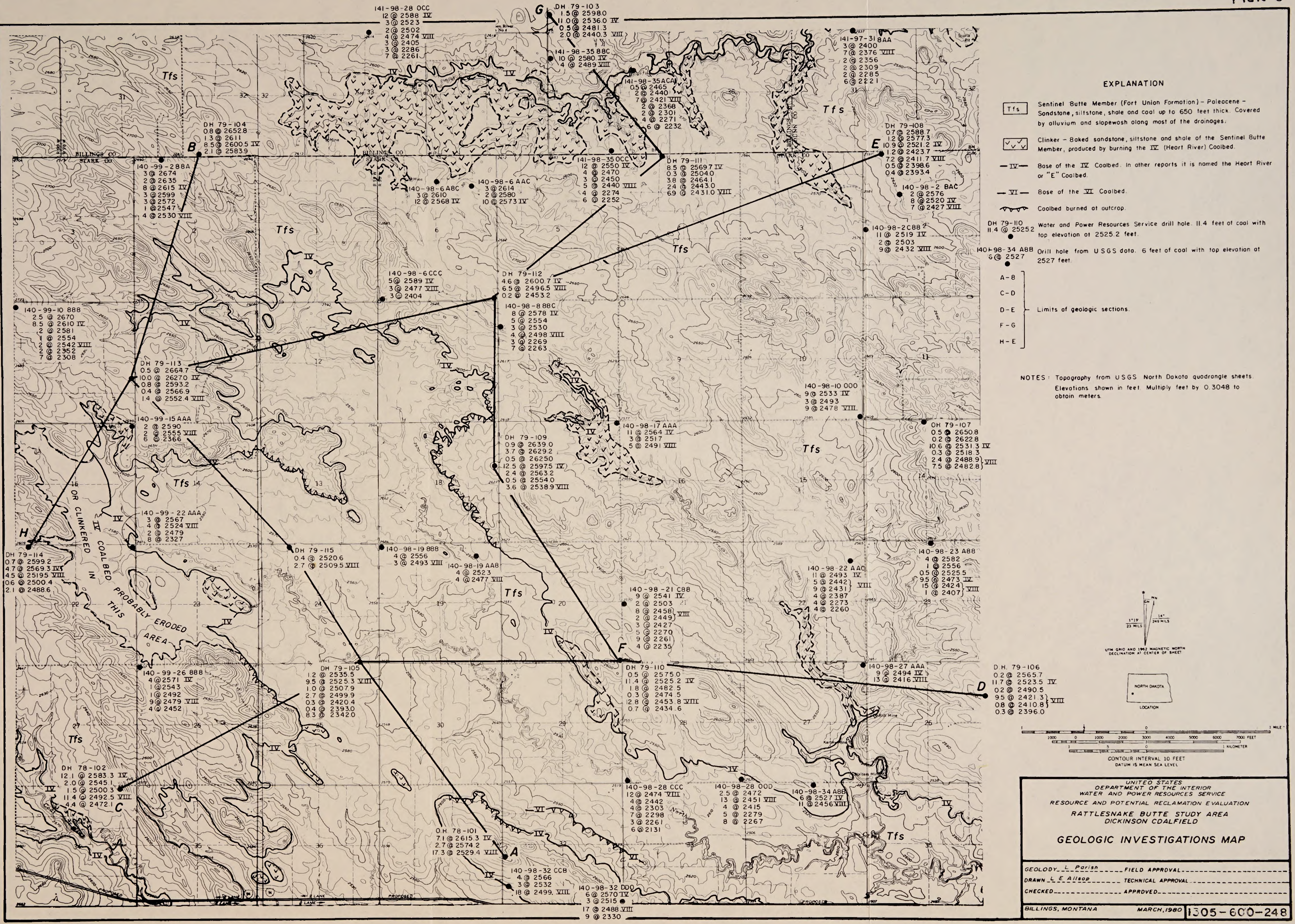
CHECKED G. J. T. APPROVED

BILLINGS, MONTANA MARCH 1976

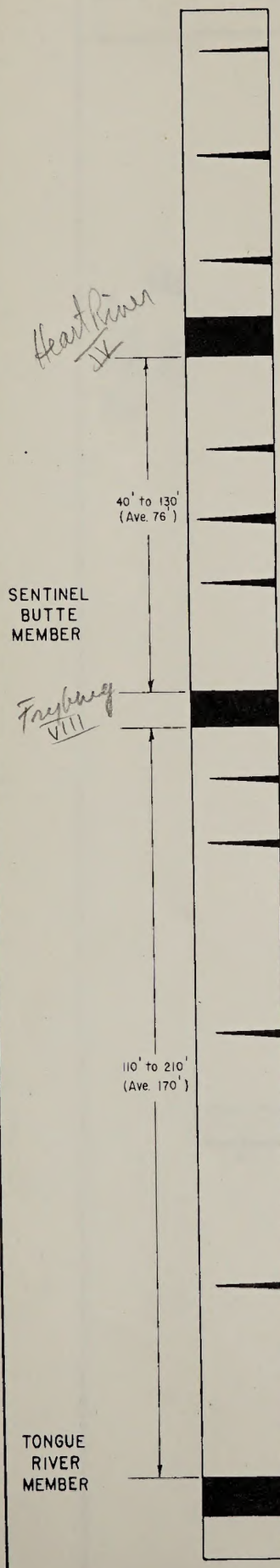
1305-600-247



Plate 5


EXPLANATION
Tfs Sentinel Butte Member (Fort Union Formation) - Paleocene - Sandstone, siltstone, shale and coal up to 650 feet thick. Covered by alluvium and slopewash along most of the drainages.
Clinker - Baked sandstone, siltstone and shale of the Sentinel Butte Member, produced by burning the IV (Heart River) Coalbed.
Base of the IV Coalbed. In other reports it is named the Heart River or "E" Coalbed.
Base of the VI Coalbed.
Coalbed burned at outcrop.
DH 79-110 11.4 @ 2525.2 Water and Power Resources Service drill hole. 11.4 feet of coal with top elevation of 2525.2 feet.
140-98-34 ABB 6 @ 2527 Drill hole from USGS data. 6 feet of coal with top elevation of 2527 feet.
A-B C-D D-E F-G H-E Limits of geologic sections.
NOTES: Topography from USGS North Dakota quadrangle sheets. Elevations shown in feet. Multiply feet by 0.3048 to obtain meters.
UTM GRID AND 1962 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
NORTH DAKOTA
LOCATION
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL
UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION
RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD
GEOLOGIC INVESTIGATIONS MAP
GEOLOGY L. Parish FIELD APPROVAL
DRAWN L. E. Allsop TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MARCH, 1980 1305-600-248
141-98-28 OCC 12 @ 2588 IV 3 @ 2523 2 @ 2502 4 @ 2474 VIII 3 @ 2405 3 @ 2286 7 @ 2261
DH 79-103 1.5 @ 2598.0 11.0 @ 2536.0 IV 0.5 @ 2481.3 2.0 @ 2440.3 VIII
141-98-35 BBC 10 @ 2580 IV 4 @ 2489 VIII
141-98-35 ACA 0.5 @ 2465 2 @ 2440 7 @ 2421 VIII 2 @ 2368 2 @ 2301 4 @ 2271 6 @ 2232
141-97-31 BAA 3 @ 2400 7 @ 2376 VIII 2 @ 2356 2 @ 2309 2 @ 2285 6 @ 2221
DH 79-104 0.8 @ 2652.8 1.3 @ 2611 8.5 @ 2600.5 IV 2.1 @ 2583.9
140-99-28 BA 3 @ 2674 2 @ 2635 8 @ 2615 IV 3 @ 2599 3 @ 2572 1 @ 2547 4 @ 2530 VIII
140-98-6 ABC 3 @ 2610 12 @ 2568 IV
140-98-6 AAC 3 @ 2614 2 @ 2580 10 @ 2573 IV
141-98-35 OCC 12 @ 2550 IV 4 @ 2470 3 @ 2450 5 @ 2440 VIII 4 @ 2274 6 @ 2252
DH 79-111 8.5 @ 2569.7 IV 0.3 @ 2504.0 3.8 @ 2464.1 2.4 @ 2443.0 6.9 @ 2431.0 VIII
DH 79-108 0.7 @ 2588.7 1.2 @ 2577.3 10.9 @ 2521.2 IV 1.2 @ 2423.7 7.2 @ 2411.7 VIII 0.5 @ 2398.6 0.4 @ 2393.4
140-98-2 BAC 2 @ 2576 8 @ 2520 IV 7 @ 2427 VIII
140-98-2 CBB 11 @ 2519 IV 2 @ 2503 9 @ 2432 VIII
140-99-10 BBB 2.5 @ 2670 8.5 @ 2610 IV 2 @ 2581 1 @ 2554 2 @ 2542 VIII 2 @ 2352 7 @ 2308
140-98-6 CCC 5 @ 2589 IV 3 @ 2477 VIII 3 @ 2404
DH 79-112 4.6 @ 2600.7 IV 6.5 @ 2496.5 VIII 0.2 @ 2453.2
140-98-8 BBC 8 @ 2578 IV 5 @ 2554 3 @ 2530 4 @ 2498 VIII 3 @ 2269 7 @ 2263
DH 79-113 0.5 @ 2664.7 10.0 @ 2627.0 IV 0.8 @ 2593.2 0.4 @ 2566.9 1.4 @ 2552.4 VIII
140-99-15 AAA 2 @ 2590 2 @ 2555 VIII 6 @ 2366
140-98-10 OOO 9 @ 2533 IV 3 @ 2493 9 @ 2478 VIII
140-98-17 AAA 11 @ 2564 IV 3 @ 2517 5 @ 2491 VIII
DH 79-109 0.9 @ 2639.0 3.7 @ 2629.2 0.5 @ 2625.0 12.5 @ 2597.5 IV 2.4 @ 2563.2 0.5 @ 2554.0 3.6 @ 2538.9 VIII
DH 79-107 0.5 @ 2650.8 0.2 @ 2622.8 10.6 @ 2531.3 IV 0.3 @ 2518.3 2.4 @ 2488.9 7.5 @ 2482.8 VIII
140-99-22 AAA 3 @ 2567 4 @ 2524 VIII 2 @ 2479 8 @ 2327
DH 79-114 0.7 @ 2599.2 4.7 @ 2569.3 IV 4.5 @ 2519.5 VIII 0.6 @ 2500.4 2.1 @ 2488.6
DH 79-115 0.4 @ 2520.6 2.7 @ 2509.5 VIII
140-98-19 BBB 4 @ 2556 3 @ 2493 VIII
140-98-19 AAB 4 @ 2523 4 @ 2477 VIII
140-98-23 ABB 4 @ 2582 1 @ 2556 0.5 @ 2525.5 9.5 @ 2473 IV 15 @ 2424 1 @ 2407 VIII
140-98-22 AAC 11 @ 2493 IV 5 @ 2442 9 @ 2431 VIII 4 @ 2387 4 @ 2273 4 @ 2260
140-98-21 CBB 9 @ 2541 IV 2 @ 2503 8 @ 2458 2 @ 2449 VIII 3 @ 2427 5 @ 2270 9 @ 2261 4 @ 2235
OR CLINKERED IN THIS IV COAL BED PROBABLY ERODED AREA
140-99-26 BBB 4 @ 2571 IV 1 @ 2543 1 @ 2492 9 @ 2479 VIII 4 @ 2452
DH 79-105 1.2 @ 2535.5 9.5 @ 2525.3 VIII 1.0 @ 2507.9 2.7 @ 2499.9 0.3 @ 2420.4 0.4 @ 2393.0 8.3 @ 2342.0
DH 79-110 0.5 @ 2575.0 11.4 @ 2525.2 IV 1.8 @ 2482.5 0.3 @ 2474.5 12.8 @ 2453.8 VIII 0.7 @ 2434.6
140-98-27 AAA 9 @ 2494 IV 13 @ 2416 VIII
D.H. 79-106 0.2 @ 2565.7 11.7 @ 2523.5 IV 0.2 @ 2490.5 9.5 @ 2421.3 0.8 @ 2410.8 VIII 0.3 @ 2396.0
DH 78-102 12.1 @ 2583.3 IV 2.0 @ 2545.1 1.5 @ 2500.3 11.4 @ 2492.5 VIII 4.4 @ 2472.1
140-98-28 CCC 12 @ 2474 VIII 4 @ 2442 4 @ 2303 7 @ 2298 3 @ 2261 6 @ 2131
140-98-28 ODD 2.5 @ 2472 13 @ 2451 VIII 4 @ 2415 5 @ 2279 8 @ 2267
140-98-34 ABB 6 @ 2527 IV 11 @ 2456 VIII
DH 78-101 7.1 @ 2615.3 IV 2.7 @ 2574.2 17.3 @ 2529.4 VIII
140-98-32 CCB 4 @ 2566 3 @ 2532 18 @ 2499 VIII
140-98-32 DDD 6 @ 2570 IV 3 @ 2515 17 @ 2488 VIII 9 @ 2330
BILLINGS CO
STARK CO
DUNN CO
Tfs

GENERALIZED STRATIGRAPHIC COLUMN - COAL AND CARBONACEOUS SHALE BEDS
RATTLESNAKE BUTTE STUDY AREA - DICKINSON COALFIELD - NORTH DAKOTA
PORTION OF THE FORT UNION FORMATION



I – 0.5 to 1.0 ft. Present in the northern part of the study area and an extreme highs in the southern part. Discontinuous or carbonaceous shale in areas. Approximately 50 to 75 ft. above the IV,(E) or Heart River Coalbed.

II – 0.5 to 3.0 ft. Eroded from all except extreme highs in the southern part of the study area. The thickest zones may be recoverable. Discontinuous or carbonaceous shale in some areas. 10 to 55 ft. above the IV,(E) or Heart River Coalbed.

III – 1.0 to 2.0 ft. Present in only a few drill holes. Discontinuous or carbonaceous shale in most of the study area. Approximately 5 to 20 ft. above the IV,(E) or Heart River Coalbed.

IV – 4.0 to 12.0 ft. (Ave. 8.7 ft.) Thins in west central part of the study area. Eroded from much of the south central part of the the study area. Approximately 40 to 130 ft. above the VIII, (D) or Fryburg Coalbed. Heart River Coalbed.

V – 0.3 and 3.0 ft. Present in only two drill holes in the northern edge of the study area. Possibly local beds at each drill site that may not be related to each other. Lies 8 and 57.2 ft. below the IV, (E) or Heart River Coalbed.

VI – 1.0 to 4.0 ft. Clinkered in thickest zones in the southern part of the study area. Discantinous or carbonaceous shale in other areas. Approximately 20 to 50 ft. below the IV, (E) or Heart River Coalbed.

VII – 0.5 to 3.0 ft. Discontinuous or carbonaceous shale in ports of the study area. Approximately 35 to 65 ft. below the IV, (E) or Heart River Coalbed.

VIII – 1.4 to 18.0 ft. (Ave. 8.4 ft.) Thickest along the southern edge of the study area. Thinnest in the northwest. Some drill holes in the east central part of the study area contain a thin shale parting. Approximately 40 to 110 ft. (Ave. 76 ft.) below the IV, (E) or Heart River Coalbed. Fryburg Coalbed

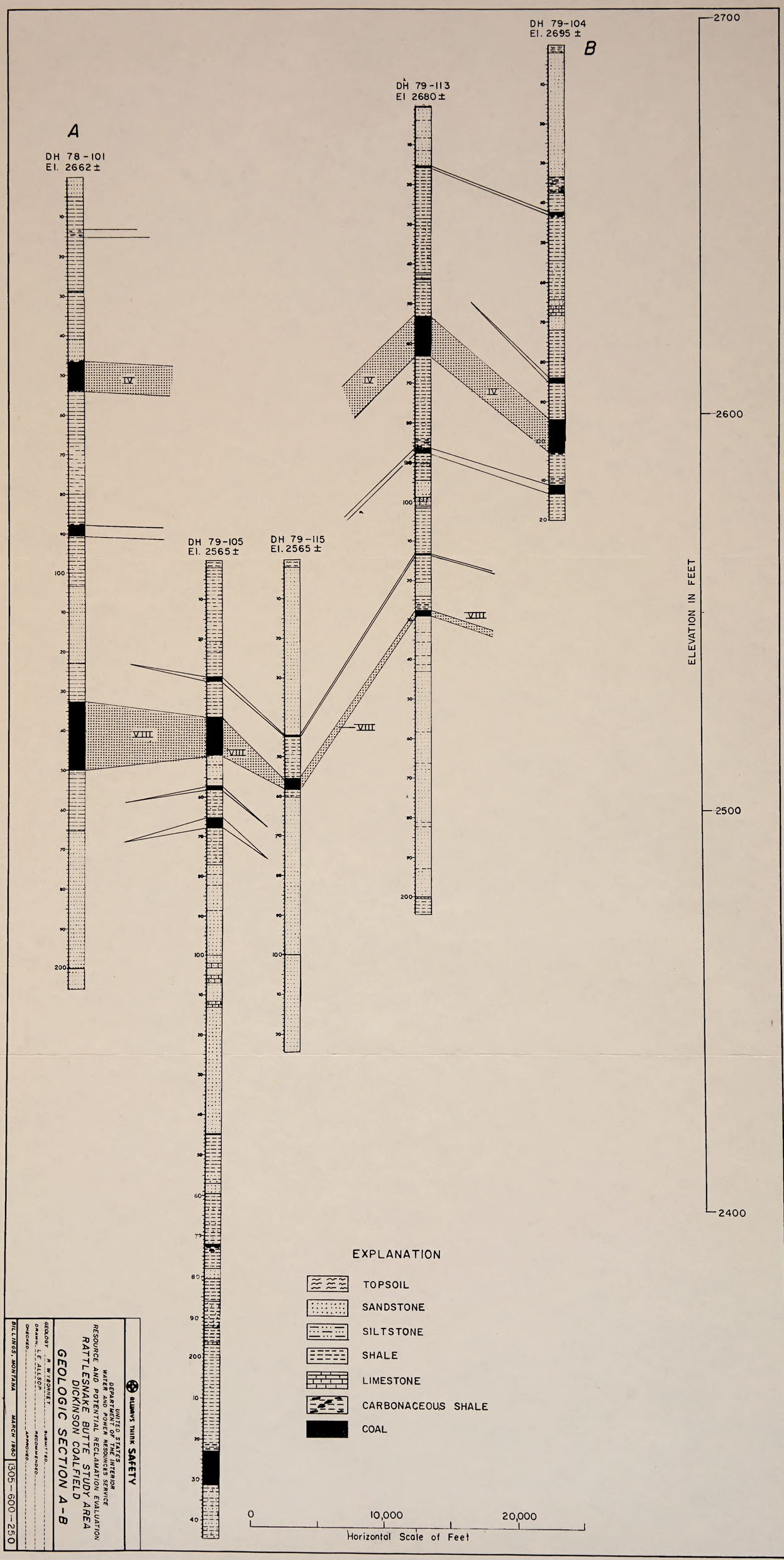
IX – 1.0 to 1.5 ft. Discontinuous or carbonaceous shale in parts of the study area. Approximately 6 to 15 ft below the VIII, (D) or Fryburg Coalbed.

X – 1.0 to 3.0 ft. Discontinuous or carbonaceous shale in parts of the study area. Approximately 15 to 35 ft below the VIII, (D) or Fryburg Coalbed.

XI – 0.5 to 2.0 ft. Discontinuous or carbonaceous shale in parts of the study area. Approximately 65 to 70 ft below the VIII, (D) or Fryburg Coalbed.

XII – 1.0 to 2.0 ft. Discontinous or carbonaceous shale in parts of the study area. Approximately 110 to 140 ft. below the VIII, (D) or Fryburg Coalbed.

XIII – 6.0 to 100 ft (Ave. 8.0 ft.) About 150 to 190 ft. below the VIII, (D) or Fryburg Coalbed. HT Butte 1 Coalbed.



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RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD

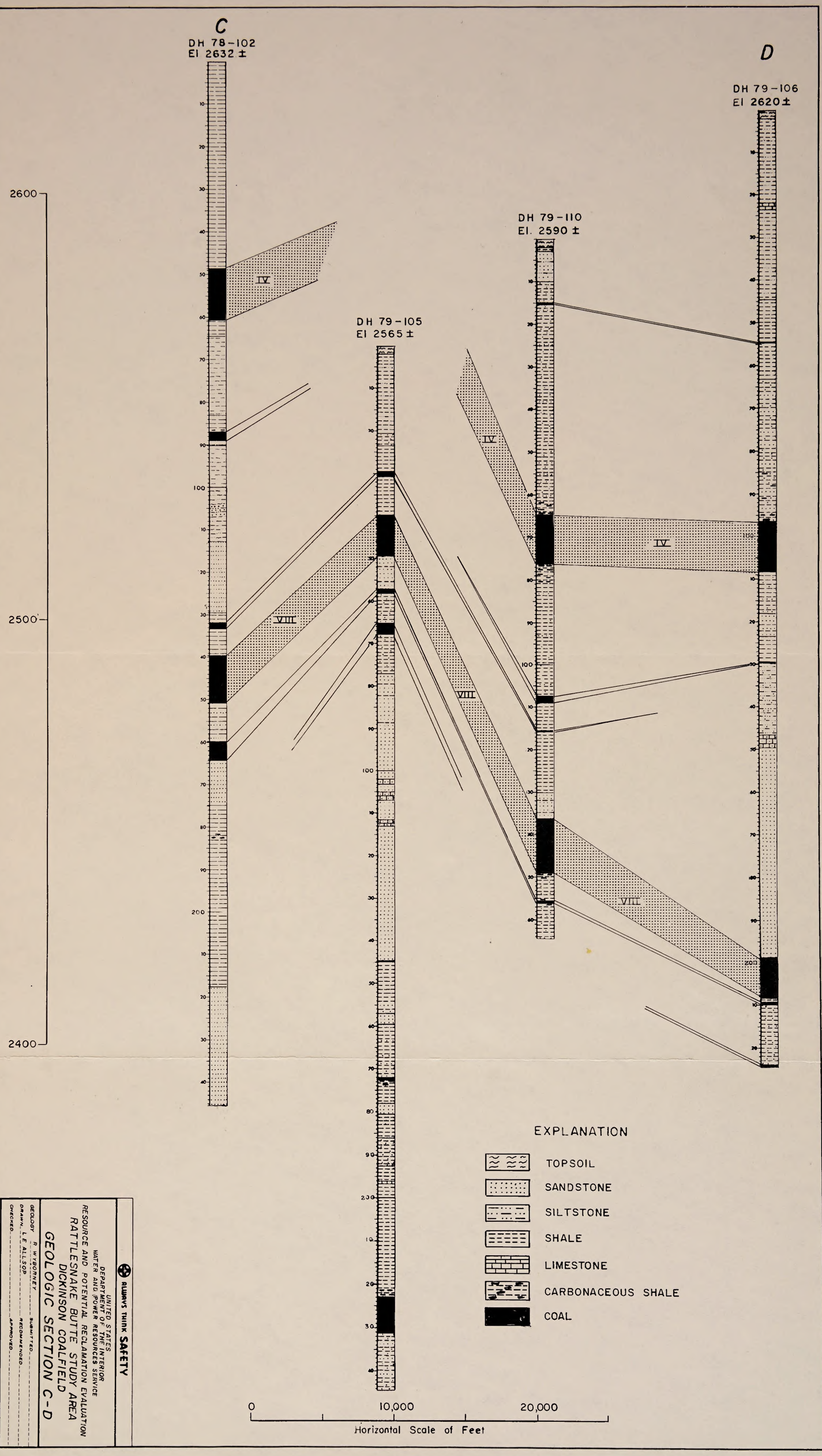
GEOLOGIC SECTION A-B

GEOLOGY R. W. BOSNIET ..... SUBMITTED .....
DRAWN L.E. ALLSOP ..... RECOMMENDED .....
CHECKED ..... APPROVED .....

BILLINGS, MONTANA | MARCH 1980 | 1305-600-250

Plate 7





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WATER AND POWER RESOURCES SERVICE

RESOURCE AND POTENTIAL RECLAMATION EVALUATION

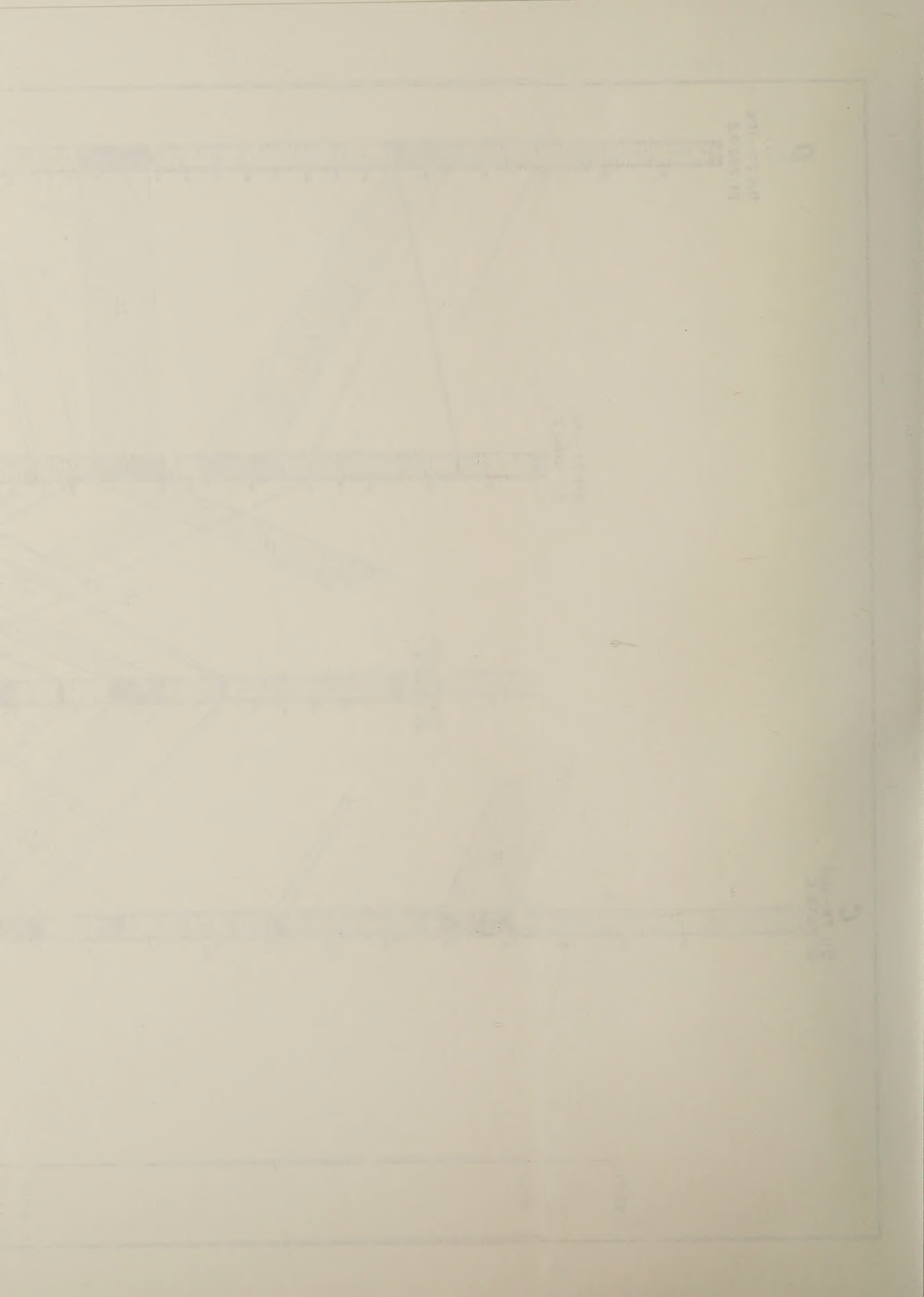
RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD

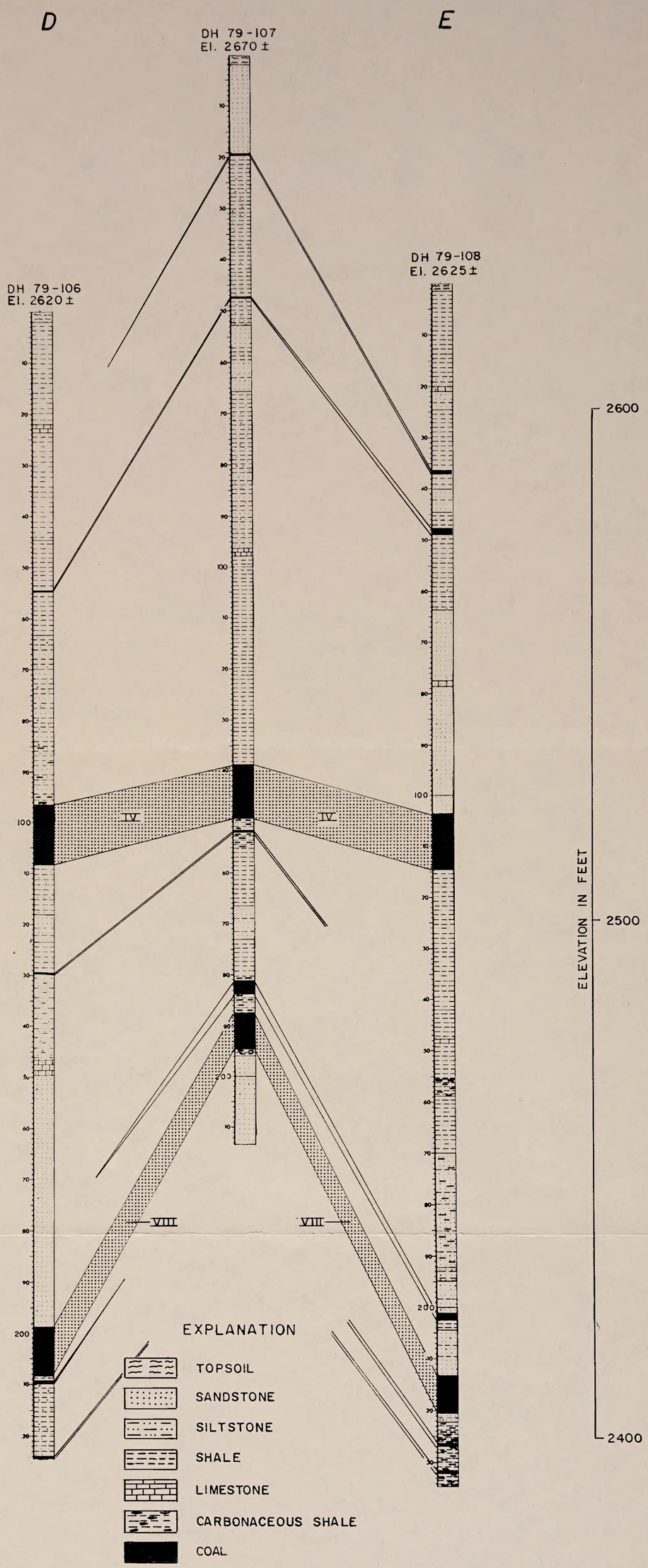
GEOLOGIC SECTION C-D

GEOLOGY R. WYBORNEY — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — MARCH 1980 — 1305-600-2E1

Plate 8





RLM WE'VE THINK SAFETY

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WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD

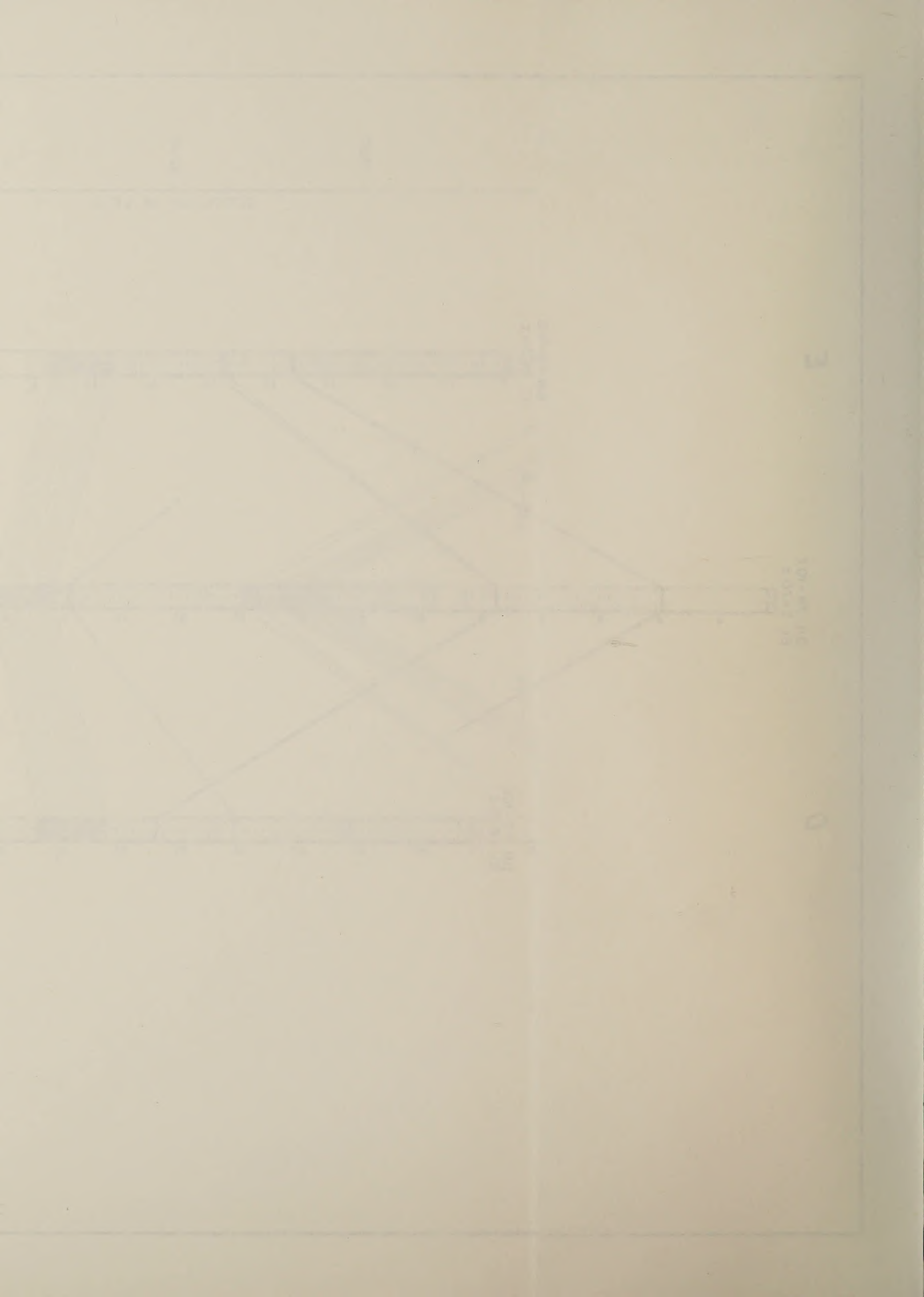
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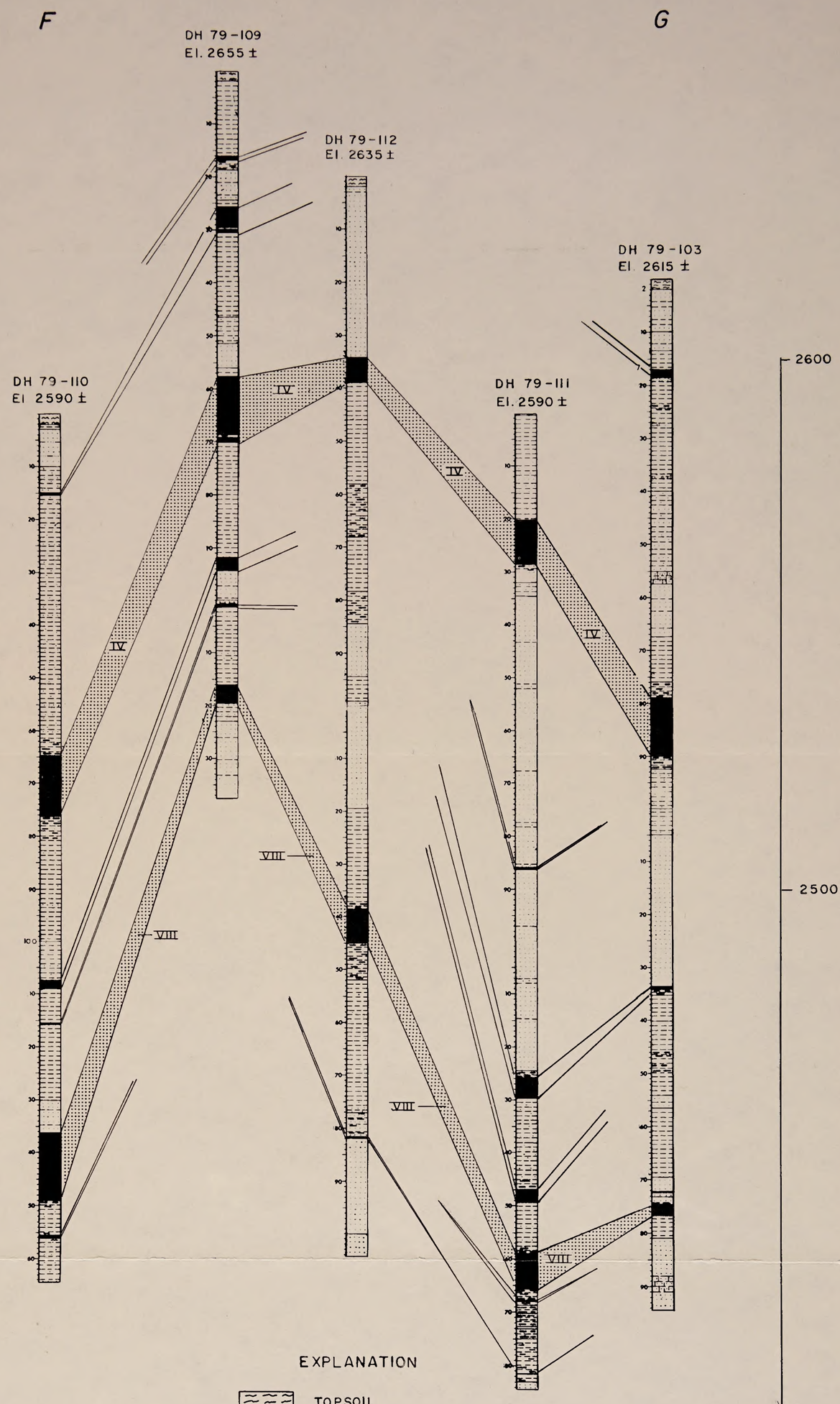
GEOLOGY R. WYBORNEY — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — MARCH 1980

1305-600-252

Plate 9





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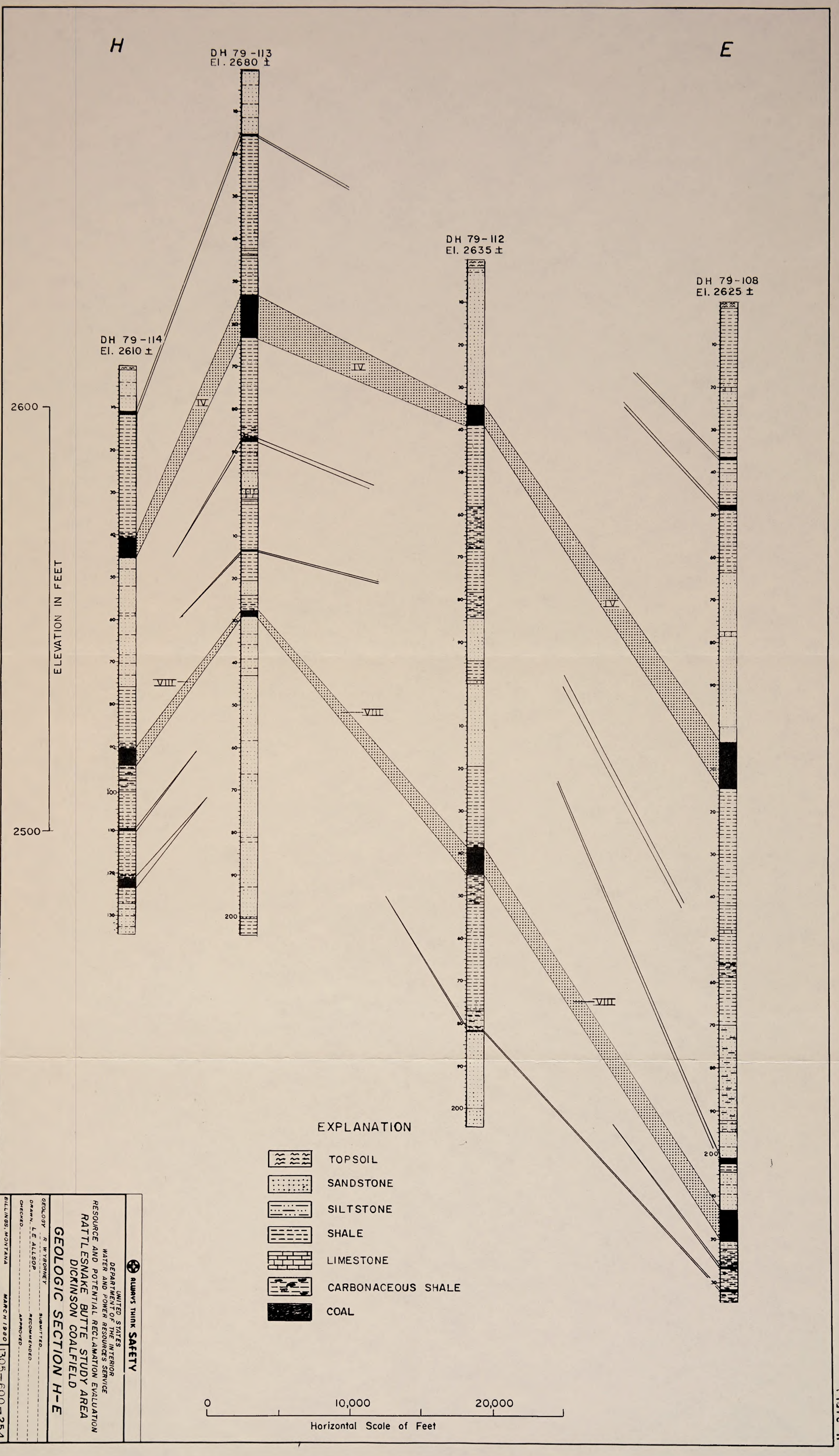
RESOURCE AND POTENTIAL RECLAMATION EVALUATION
RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD

GEOLOGIC SECTION F-G

GEOLOGY R. WYBORNEY — SUBMITTED
DRAWN L.E. ALLISON — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA | MARCH 1980 | 1305-60-253

Plate 10



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DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION
RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD

GEOLOGIC SECTION H-E

GEOLOGY R. W. GORNEY — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — MARCH 1980 — 1305-600-254

Plate 11

or siliceous cemented concretions. In general, the sandstones are fine grained and uncemented. Shales vary from soft, plastic clayshale to moderately indurated claystone. Shale and siltstone zones readily break down and form slopes beneath sandstone ledges. Correlation of clastic sediments over short distances is difficult due to facies changes, channeling and variation in bedding thickness. Laboratory analyses conducted on core samples from the Rattlesnake Butte Study Area indicate that chemical and physical properties of the bedrock generally cannot be projected between drill holes. Weathered exposures are usually pale olive or yellowish-gray in color; while fresh core samples vary from light to dark gray. Marcasite and/or pyrite nodules are found along zones of higher permeability, such as fractures and bedding planes. The Sentinel Butte Member was deposited in a continental environment which included swamps conducive to the production of thick lignite beds. Lignite zones serve as excellent markers because they can usually be traced over wide areas. This member is up to 650 feet thick.

Striking features in the Sentinel Butte and Tongue River Members are the resistant clinker zones, locally called "scoria" that cap knobs or armor valley walls. The clinker, which is fused or baked rock, was produced by the burning of lignite beds along and back from their outcrops. In places where the heat was sufficiently intense, the clinker has been fused to a dark gray, lightweight rock similar in appearance to vesicular basalt. Near the outer edge of thermal metamorphism, the rock is disoriented, baked, and red to orange in color. Alteration of the overlying material is roughly proportional to the original thickness of lignite that has burned. A lignite bed 20 feet thick will produce clinker zones 40 to 60 feet thick. The clinker is highly permeable and locally supplies water for springs and wells.

Clinker in the Rattlesnake Butte Study Area was usually produced by burning of the IV (Heart River) Coalbed. Outcrops occur along most major drainages. They are shown on the Geologic Investigations Map, Plate 5. Some of the IV Coalbed may remain beneath the clinker because subsurface explorations and surface mining in other areas indicate that lower sections of thick coalbeds are not always burned beneath clinkered areas. An extensive drilling program would be required to determine the amount of coal which underlies the thermally altered rock. For the purpose of this report, it is assumed (1) that all lignite has burned beneath clinkered areas and (2) that the contact between baked and unbaked rock is vertical.

Golden Valley Formation - Eocene - consists of about 200 feet of alternating shales, siltstones, and crossbedded sandstones. These sediments, which overlie the Sentinel Butte Member, have been eroded from the study area.

Alluvium - Holocene - consists of unconsolidated clay, silt, sand, and gravel that covers valley floors. It was not differentiated in the study area because of slopewash and the residual soil mantle.

Lignite Beds

Thirteen lignite and/or lignitic shale beds, I through XIII, were penetrated by drilling in the Rattlesnake Butte Study Area. Brief descriptions of these beds are found on the generalized stratigraphic column, Plate 6.

Two coalbeds are of primary economic significance in the study area. They are the IV and VIII Coalbeds. In previous reports, they have been named respectively the "E" or Heart River Coalbed and the "D" or Fryburg Coalbed.

The IV Coalbed is the only one that crops out in the study area. Outcrops, often clinkered, are found along most drainages. The bed has been eroded from most of the south-central part of the study area. It ranges in thickness from 4 to 12 feet, with an average of 8.7 feet. Thickness countours are shown on Plate 27. The IV Coalbed lies under less than 150 of overburden except for a few scattered highs along the east-central edge of the study area, and most of the coalbed actually has less than 100 feet of overburden resting on it (Plate 27).

The VIII Coalbed underlies the whole study area, but does not crop out. It has a wide range of thicknesses from 1.4 to 18 feet with an average of 8.4 feet. The thickest area is along the southern edge of the study area. Coalbed thickness contours are shown on Plate 28. The VIII Coalbed contains a thin parting of interburden within part of the southeastern portion of the study area. The split area is shown on Plate 28. Overburden thickness contours on Plate 28 indicate that nearly all the VIII Coalbed lies under less than 200 feet of overburden.

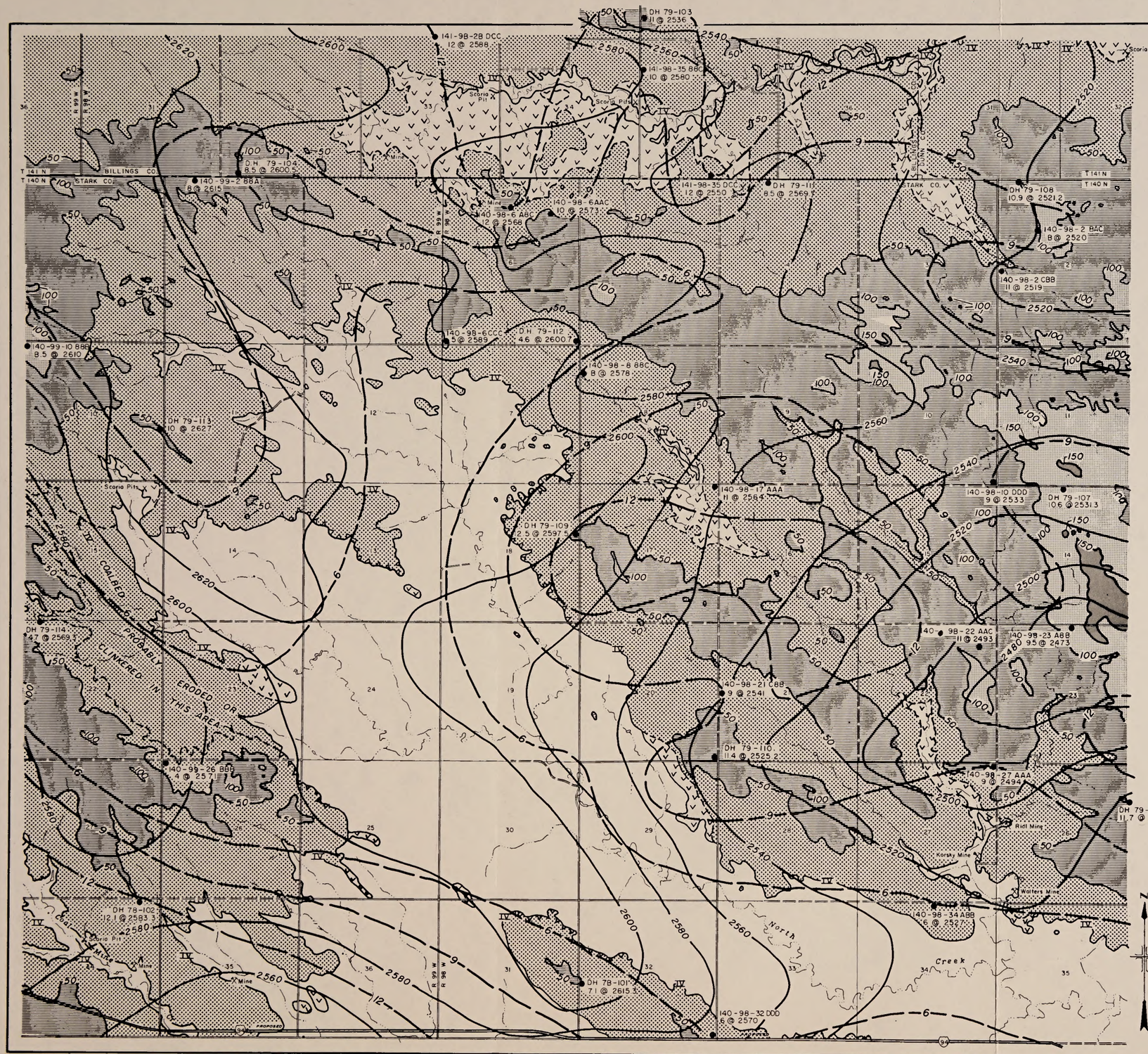
Two other coalbeds (II and VI) contain thick zones which will probably be recoverable during mining operations for more desirable coalbeds. The II Coalbed is generally limited to the northern part of the study area and the VI Coalbed to the southern part.

The XIII (HT Butte 1 Coalbed) was penetrated by drilling in the Rattlesnake Butte Study Area, and although it has a significant thickness (about 8 feet), it probably lies too deep for conventional strip mining.

Structure

The study area is located on the southwestern flank of the Williston Basin. Sediments are essentially flat lying. Structure contours drawn on top of the IV and VIII Coalbeds, Plates 27 and 28, indicate that a forked ridge trends across the area from the northwest to the south and east. Low areas occur in the northeast, southeast and southwest corners of the study area. The features may be the result of differential compaction and may not be expressed at depth.

Small local faults exist throughout the area as indicated by the slickensides exhibited in drill core samples.. These are generally restricted to



EXPLANATION

—2560— Structure contour on top of IV Coalbed.

—9— Thickness contour of IV Coalbed.

—100— Overburden thickness contour above IV Coalbed.

—IV— Base of IV Coalbed.

—VI— Base of VI Coalbed.

Coalbed burned at outcrop.

Altered shale, siltstone and sandstone (clinker) produced by burning the IV Coalbed.

● DH 79-112 4.6 @ 2600.7 — Water and Power Resource Service drill hole. 4.6 feet of coal with top elevation of 2600.7 feet.

● 140-98-6 ABC 12 @ 2568 — Drill hole from USGS data. 12 feet of coal with top elevation at 2568 feet.

OVERBURDEN ABOVE IV COALBED

- 0 to 50 feet
- 50 to 100 feet
- 100 to 150 feet
- Over 150 feet

NOTES: IV Coalbed is the "E" or Heart River Coalbed in other reports.

Elevations and thicknesses shown in feet, multiply feet by 0.3048 to obtain meters.

1000 0 1000 2000 3000 4000 5000
SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD

IV COALBED
OVERBURDEN THICKNESS MAP

GEOLOGY L. PARISH _____ FIELD APPROVAL _____
DRAWN L.E. ALLSOP _____ TECH. APPROVAL _____
CHECKED _____ APPROVED _____

BILLINGS, MONTANA MARCH, 1980 | 1305-600-270



EXPLANATION

—2460— Structure contour on top of VIII Coalbed.

—9— Thickness contour of VIII Coalbed

—100— Overburden thickness contour above VIII Coalbed. Includes higher coalbeds.

DH 79-105 9.5 @ 2525.3 — Water and Power Resources Service drill hole. 9.5 feet of coal with top elevation at 2525.3 feet.

140-98-10 DDD 9 @ 2478 — Drill hole from USGS data. 9 feet of coal with top elevation at 2478 feet.

OVERBURDEN ABOVE VIII COALBED

- 0 to 50 feet
- 50 to 100 feet
- 100 to 150 feet
- 150 to 200 feet
- Over 200 feet

NOTES: VIII Coalbed is the "D" or Fryburg Coalbed in other reports.

Elevations and thicknesses shown in feet, multiply feet by 0.3048 to obtain meters.

1000 0 1000 2000 3000 4000 5000
SCALE OF FEET

N

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD

VIII COALBED
OVERBURDEN THICKNESS MAP

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN L.E. ALLSOP — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — MARCH, 1980 — 1305-600-271

weak, plastic, carbonaceous shales immediately above or below lignite beds. Displacement along these fractures could not be determined but probably does not exceed 5 feet.

Paleontology

Geologic mapping did not reveal any significant or unusual paleontological sites in the study area. Fossils in the Sentinel Butte Member are generally obscured by the mantle of residual or alluvial soils. Fossils found in drill core samples included calcareous shells and carbonaceous tree fragments. None of these were collected for identification.

Mineral Resources

Natural gas and oil are the only minerals, other than coal, that are present in the study area. At least two wells in the area are presently producing.

Engineering Geology

Stability of Excavation Slopes

Engineering property tests were not conducted on bedrock samples from the Rattlesnake Butte Study Area. The Rattlesnake Butte rock is somewhat softer and contains more shale, but physical property test results for it should be similar to those of Fort Union Formation samples tested at the Otter Creek Study Site, Montana (EMRIA Report No. 1).

Much of the bedrock at the Rattlesnake Butte Study Area consists of bentonitic shales which are susceptible to minor shrinking and swelling. Shear strengths of the material are low, especially in a saturated condition. Slides could easily develop adjacent to high walls in surface mines, particularly along beds of weak, plastic, carbonaceous shales which are typically cut by inherent slickensides. Adequate drainage will have to be maintained to relieve pore water pressure in the overburden as mine excavations progress.

Saturated, uncemented siltstones and fine grained sandstones will readily erode and flow into excavations. This problem is sometimes encountered in drilling when the walls of holes collapse or slough. Depth of excavation will be limited by the water table until these materials are dewatered.

Excavation slopes will vary considerably between mine sites and will be dependent on exposure time, moisture conditions, material types and depth of cut. Detailed engineering studies of the overburden will be required at each location for use in determination of designed slopes.

Studies conducted at the Otter Creek site indicate that disturbed overburden (spoil banks and piles) should have slopes not greater than 4 to 1 with berms of 50 to 100 feet in width designed on the slope surface.

Stability of the Present Landscape

In its present undisturbed state, the Rattlesnake Butte Study Area experiences no problems with land stability. Landslides do not occur because of the gentle slopes and subsidence is not a problem.

Overburden Expansion

Overburden volumes expand as the materials are broken up during mining. The increase in volume (bulking or swell) differs for various types of soil and rock. Soft sandstones and shales in the Fort Union Formation will probably expand about 25 percent. In some cases, the surface of the replaced overburden will be higher after mining than the ground surface was before disturbance.

Instability of the Postmining Landscape 1/

Three types of instability are common on reclaimed coal mined areas in the Northern Great Plains. They are: (1) area-wide settling; (2) localized collapse; and (3) piping. Each type of instability is affected by variables in the postmining landscape. These include the physical and chemical characteristics of the overburden, methods and equipment used in stripping and contouring operations, and the season when these activities occur.

Area-wide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This settlement will generally be most pronounced during the first year and will continue at a decreasing rate with the progression of time.

The texture of the overburden will have a marked influence on settlement. Fine-textured (clayey) overburden usually results in more blocky and, initially, more porous spoils than does coarse-textured (sandy) overburden. Therefore, a lesser degree of settlement is expected in areas of largely sandy spoils than in areas of clayey spoils.

Equipment is also a critical factor. Settlement is significantly less in scraper-contoured areas than in dozer-contoured areas, especially if contouring is conducted in mid-winter. This is because a greater degree of compaction is achieved in scraper-contouring operations than in dozer-contouring operations.

Local collapse features develop soon after contouring and usually complete development within a year. They commonly occur in precontouring valley areas where frozen spoil blocks are concentrated by final, mid-winter dozer contouring. Thawing of these blocks results in local surface subsidence. In contrast, areas contoured in mid-winter with a scraper are stable because large blocks of frozen spoil are broken apart, spread, and compacted. This type of landscape instability is, therefore, largely equipment and seasonally controlled.

1/ Groenewold, G.H., and Rehm, B.W., 1980.

Piping appears to be a severe and long term problem in some postmining landscapes. Development usually begins soon after contouring and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years of apparent stability. It is controlled by a combination of physical and chemical conditions in the spoils.

A key factor in the development of piping features is the cracking of spoils in areas containing highly dispersive sodic material. These cracks allow access for large volumes of surface runoff to flow into the subsurface. Piping generally develops on nearly flat slopes where surface runoff is minimal and infiltration is maximized.

Piping, like other instability problems, most commonly develops in areas contoured by dozers. Scraper-contoured areas generally are better compacted, thus providing fewer subsurface avenues for infiltration of surface water.

Weathering Tests

Objectives

Laboratory weathering and outdoor exposure tests were conducted on overburden samples from the Rattlesnake Butte Study Area. The purpose of these tests was to determine which materials would break down sufficiently to allow for their possible use as planting media in revegetation of strip-mined areas.

Test Procedures

Specimens for the laboratory weathering and outdoor exposure tests were cut from core samples submitted by the Regional Director, Billings, Montana, under his memorandum dated October 1, 1979.

The reason for including outdoor exposure tests was to determine if any correlation could be drawn between natural weathering and the laboratory weathering conditions.

The laboratory weathering cycle consisted of the following conditions:

Freeze-Thaw Cycle

1. Eight hours at 75°F. (23.9°C.), 100 percent relative humidity (wetting/thawing).

2. Sixteen hours (64 hours on weekends) at 0°F. (-17.8°C.) (freezing).

Wet-Dry Cycle

1. Eight hours at 75°F. (23.9°C.), 100 percent relative humidity (wetting).

2. Sixteen hours (64 hours on weekends) at 100°F. (37.8°C.), 10 percent relative humidity (drying).

The core specimens tested were approximately 50 mm (2 inches) in length. For testing and handling, each core specimen was placed on a No. 10 mesh screen in a 400-ml plastic beaker.

Laboratory weathering tests were started on January 22, 1980, and 20 laboratory weathering cycles were completed on March 24, 1980. For natural weathering, the core specimens were placed in the outdooor exposure test area at the E&R Center on January 22, 1980. These specimens were evaluated after 10 weeks and again after 1 year of weathering.

During the 1- year period of time, the specimens were subjected to about 356 mm (14 inches) of precipitation, with over half occurring in May and June.

Tests Results

Laboratory Weathering

Test results of laboratory weathering are summarized in Table 3, Appendix B, and shown visually on Photographs 6 through 10, Appendix B.

At the completion of the laboratory weathering tests, a percent breakdown value (%BD) was determined for the specimens. This value listed under the Remarks column in the tables was derived as follows:

$$\%BD = \frac{TW - IW\ (100)}{TW}$$

where

TW = total specimen weight

IW = weight of original specimen remaining intact after testing.

Based on discussions with the Agronomy Department, Colorado State University, concerning soil texture necessary as a planting medium (minimum of 30 percent by weight passing a No. 100 screen), only sandstone samples R-16 through R-20 from the Rattlesnake Butte Study Area broke down sufficiently to be considered for possible use as a planting media. Sandy siltstone sample R-6 broke down sufficiently, but it exhibited severe swelling when wetted and would probably be difficult to handle and place during earthmoving operations. Shale sample R-9 softened upon wetting but returned to a hard state after drying. Also, some salt leaching was noted for this material.

Outdoor Weathering

After only 10 weeks of outdoor weathering, the samples exhibited very little physical change. Test results are summarized in Table 3, Appendix B, and on Photographs 11 through 15, Appendix B.

At the end of 1 year of outdoor exposure the core samples were again evaluated. Test results are summarized in Table 4, Appendix B, and on Photographs 16 through 20, Appendix B. A percent breakdown value (%BD) was determined using the same method as for laboratory weathering, and the percent weight passing a No. 10 mesh screen was determined for each specimen. These values are listed under the Remarks Column in Table 4, Appendix B.

Of the overburden samples from the Rattlesnake Butte Study Area, all exhibited various degrees of weathering, but only four attained the soil texture necessary as a planting medium. These included shale samples R-2 and R-5, and clayey sandstone samples R-12 and R-15. However, all four swelled upon wetting and would probably be difficult to handle and place during earthmoving operations.

Material Sources

Earth materials suitable for most construction can be found within or near the Rattlesnake Butte Study Area. Material types and sources are noted below:

Impervious - clayey or silty material that can be used for construction of embankments or as canal lining. It can be obtained from the residual soil that covers part of the uplands or from local zones within the alluvium of the valley floors.

Pervious - clean sand or gravel suitable for use as filters or other types of structures where free drainage is required. It can probably be found in selected sites along Heart or Green River, a few miles from the study area.

Concrete Aggregate - clean sand and gravel similar to the pervious material noted previously. Some is found in local deposits along the Green River, but it has not been very satisfactory. Most Dickinson ready-mix firms use aggregate hauled in from near Glendive, Montana, a distance of about 100 miles.

Clinker (Scoria) - thermally altered rock formed by heat from the burning of coalbeds. It is usually reddish in color, reasonably hard and brittle. It crushes easily and in commonly used for road fill and surfacing. It can be found in several places within the study area where the IV Coalbed has burned along its outcrop.

Riprap - durable, reasonably well-graded mixture of rock fragments generally ranging from about 6 inches to 2 or 3 feet diameter used for surface protection from running water. Ideally, individual fragments should be angular to remain stable on steep slopes. No riprap sources are within the Rattlesnake Study Area. A sandstone quarry a few miles south of Dickinson produces material that has been used by the city for bank protection, but the material lacks durability and would have to be replaced periodically. Probably the closest sources of suitable rock are the Black Hills of South Dakota or the granitic basement rocks of extreme eastern North Dakota.

Seismic

The Rattlesnake Butte Study Area lies within a relatively stable part of North America. All of North Dakota is within Zone 1 of the Algermisson Seismic Risk Map. In this zone distant earthquakes can cause minor damage to structures with

fundamental periods greater than 1.0 second. (Corresponds to intensities V and VI of the Modified Mercalli Intensity Scale of 1931).

No earthquakes of intensity V or above (Modified Mercalli) have occurred within North Dakota during historical times. Earthquakes centered in Iowa, Minnesota, Montana, Nebraska, and a Canadian shock have been felt in the state. A list of earthquakes that have been felt in North Dakota follows, but much of the information on exact location and intensity is unknown.

Date	Intensity (Modified Mercalli)	Distance From Rattlesnake Butte Study Area	Located Near
Oct. 9, 1872	Unknown	425 miles	Sioux City, IA
Nov. 15, 1877	Unknown	Unknown	IA or NE
May 15, 1909	Unknown	Unknown	SK, Canada
Oct. 26, 1946	IV	95 miles	Williston, ND
Aug. 17, 1959	IX	435 miles	Hebgen Lake, MT
July 8, 1968	IV	110 miles	Huff, ND
July 9, 1975	Unknown	330 miles	Morris, NM

COAL RESOURCES[1/]

Introduction

This report was prepared as a contribution to the study of the reclamation potential of the Rattlesnake Butte EMRIA study site in the Dickinson coal field in southwestern North Dakota (Fig. 2). The area was selected by the U.S. Bureau of Land Management to be included in the EMRIA (Energy Minerals Rehabilitation Inventory and Analysis) program in order to evaluate the reclamation potential of sediments from the Tertiary Fort Union Formation in this part of the Williston Basin.

The Rattlesnake Butte EMRIA study site comprises about 12,800 acres of land underlain by Federally owned coal in an area of approximately 35,000 acres where the surface rights are under private ownership (Table 6). The study site has its unusual configuration due to the "checkboard" pattern of federally owned mineral rights (Fig. 2) that dates back to the railroad grants made by Congress in 1862, where railroad corporations were to receive every alternate section of land in belts ranging in width from 20 to 40 miles on each side of the railroad (Bass, Smith and Horn, 1970). The area is located 12 miles (18 km) to the west of the city of Dickinson, North Dakota, within the Belfield, Belfield NE, Fairfield SE, New Hradec North, and New Hradec South 7½ minute quadrangles.

Coals of the Rattlesnake Butte study site were evaluated on the basis of drill-hole data and surface studies. During January and February of 1978 and January through April of 1979, the Bureau of Reclamation mapped the surface geology and drilled fifteen holes using continuous coring methods for the EMRIA program. Twenty-nine additional rotary holes were drilled during the 1978 and 1979 field seasons by the U.S. Geological Survey in the vicinity of the study site (Fig. 2).

Stratigraphy

The Paleocene Fort Union Formation contains the three lignite beds evaluated for the Rattlesnake Butte study site. In this area the Fort Union Formation consists of four members, in ascending order, the Cannonball, Ludlow, Tongue River, and Sentinel Butte (Fig. 3).

The marine Cannonball Member consists of sandstone and shale. It intertongues with the overlying nonmarine Ludlow Member, which consists of sandstone, siltstone, shale, and lenticular lignite beds. The nonmarine Tongue River and Sentinel Butte Members both consist of sandstone, siltstone, shale, and one or more thick continuous lignite beds. The contact between the Tongue River Member and the Sentinel Butte Member is placed at the top of the HT Butte lignite bed. Only the Sentinel Butte Member crops out in the study site.

The three lignite beds of significant thickness in this area are: the HT Butte (or XIII) lignite bed in the Tongue River Member; the Fryburg (or VIII) lignite bed and the Heart River (or IV) lignite bed in the Sentinel Butte Member.

1/ A section describing the origin, classification, rank, type, and grade of coal is included for reference in Appendix C.

The stratigraphically lowest bed, the HT Butte bed, which was penetrated in 13 drill holes, ranges in thickness from 4 to 14 feet (1.2 to 4.3 m) at depths of 200 feet (61 m) or more. In six holes, in the eastern part of the study site, the bed splits into two beds. Interburden between the two beds ranges from 7 to 42 feet (2.1 to 12.8 m) thick. Where interburden thickness exceeds the upper lignite thickness, the upper coal is referred to as the HT Butte rider lignite bed. The lignite in the rider ranges from 2 to 5 feet (0.6 to 1.5 m) thick.

The Fryburg bed, which was penetrated in 41 drill holes, is 85 to 195 feet (26 to 59 meters) above the HT Butte bed, and ranges from 1.4 to 18 feet (0.4 to 5.5 m) thick at depths of 35 to 198 feet (10.7 to 60.3 m). In the southeastern part of the study site, the bed contains a thin parting of rock. This lignite bed does not crop out anywhere in the study site.

The uppermost bed, the Heart River bed, which was penetrated in 33 drill holes, is 31 to 130 feet (9 to 40 m) above the Fryburg bed, and ranges from 4 to 12.5 ft (1.2 to 3.8 m) thick at depths of 13 to 139 feet (4 to 42.4 m). This lignite bed crops out in this area and in places has burned on outcrop, producing heat that has baked the overlying rocks into brittle, resistant, reddish rock called clinker. For the purposes of calculating coal resources, it is assumed that the contact between burned and unburned lignite is vertically below the contact between baked and unbaked rock.

Chemical analysis of coal in the Rattlesnake Butte Study Site

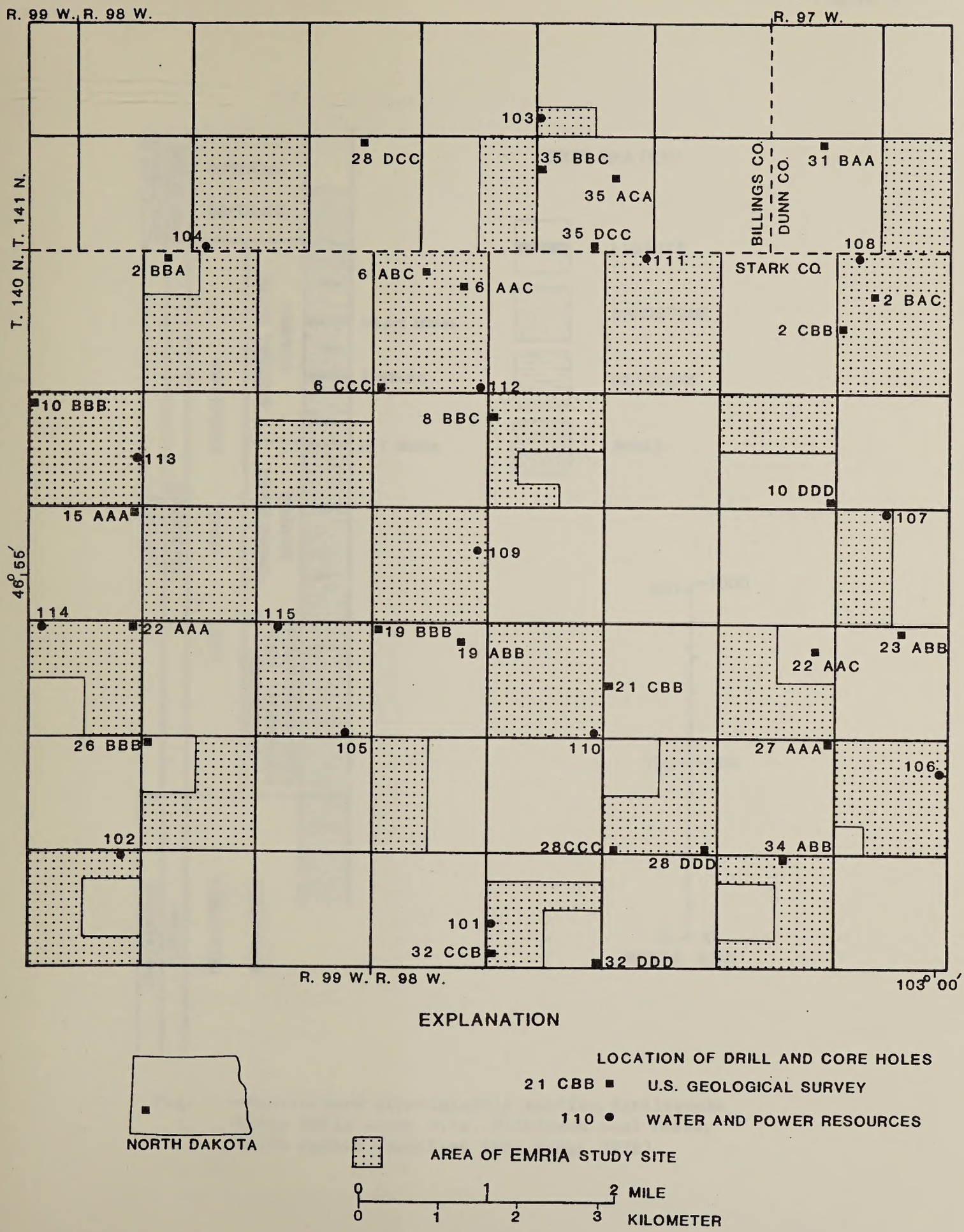
Proximate analysis, sulfur content, and heat content on 19 lignite samples (Table 7) were provided by chemists from the Coal Analysis Section (John Puskas, Acting Chief), U.S. Department of Energy, Pittsburgh, Pa., whose contribution is gratefully acknowledged.

Seven samples taken from the Heart River lignite bed in the Rattlesnake Butte study site have ash contents that range from 5.5 to 9.1 percent, averaging 6.4 percent, and have sulfur contents that range from 0.4 to 2.6 percent, averaging 0.8 percent. Nine samples taken from the Fryburg lignite bed in the Rattlesnake Butte study site have ash contents that range from 8.9 to 17.2 percent, averaging 12.2 percent, and have sulfur contents that range from 0.3 to 3.0 percent, averaging 1.1 percent. The HT Butte lignite bed was not sampled in this area. A more detailed breakdown of analyses of the Heart River and Fryburg lignite beds is in Table 7. Compared to 488 samples of other U.S. coal (Swanson and others, 1976), lignite of the Heart River bed has relatively high moisture content, low sulphur content, low heat of combustion, and low ash content; when applying the same comparison to the lignite of the Fryburg bed, the Fryburg has relatively high moisture content, low sulfur content, a low heat of combustion, and a slightly higher ash content.

Characteristics Used in Resource Evaluation

The coal characteristics that are commonly used in classifying coal resources are: rank, grade, and density of the coal; thickness of the coal beds; and thickness of the overburden. Rank and grade are discussed in Appendix C.

Figure 2



EXPLANATION

NORTH DAKOTA

LOCATION OF DRILL AND CORE HOLES

21 CBB ■ U.S. GEOLOGICAL SURVEY

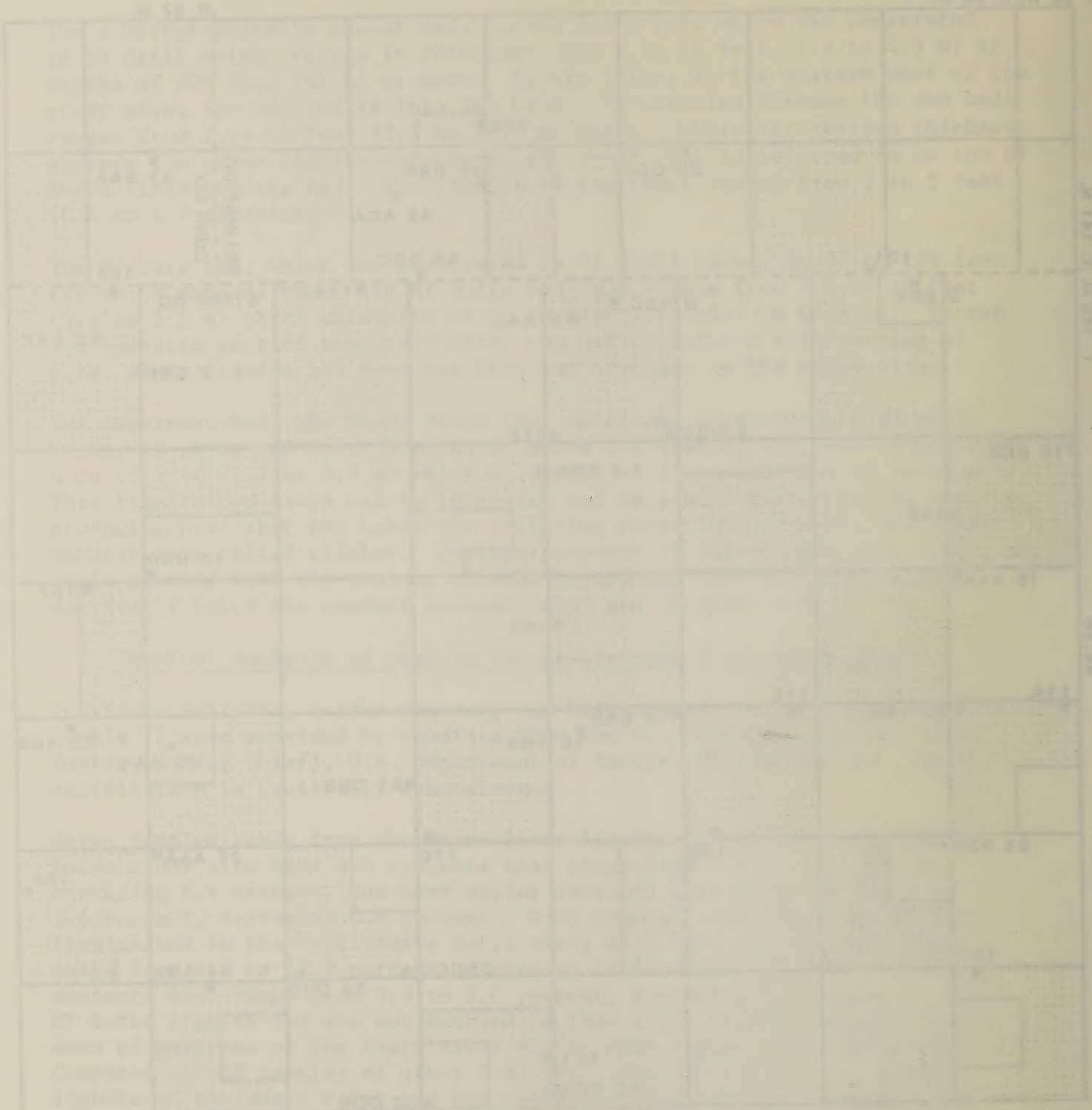
110 ● WATER AND POWER RESOURCES

AREA OF EMRIA STUDY SITE

0 1 2 MILE

0 1 2 3 KILOMETER

Fig. 2 --Index map of the Rattlesnake Butte EMRIA study site, Stark, Billings and Dunn Counties, North Dakota.



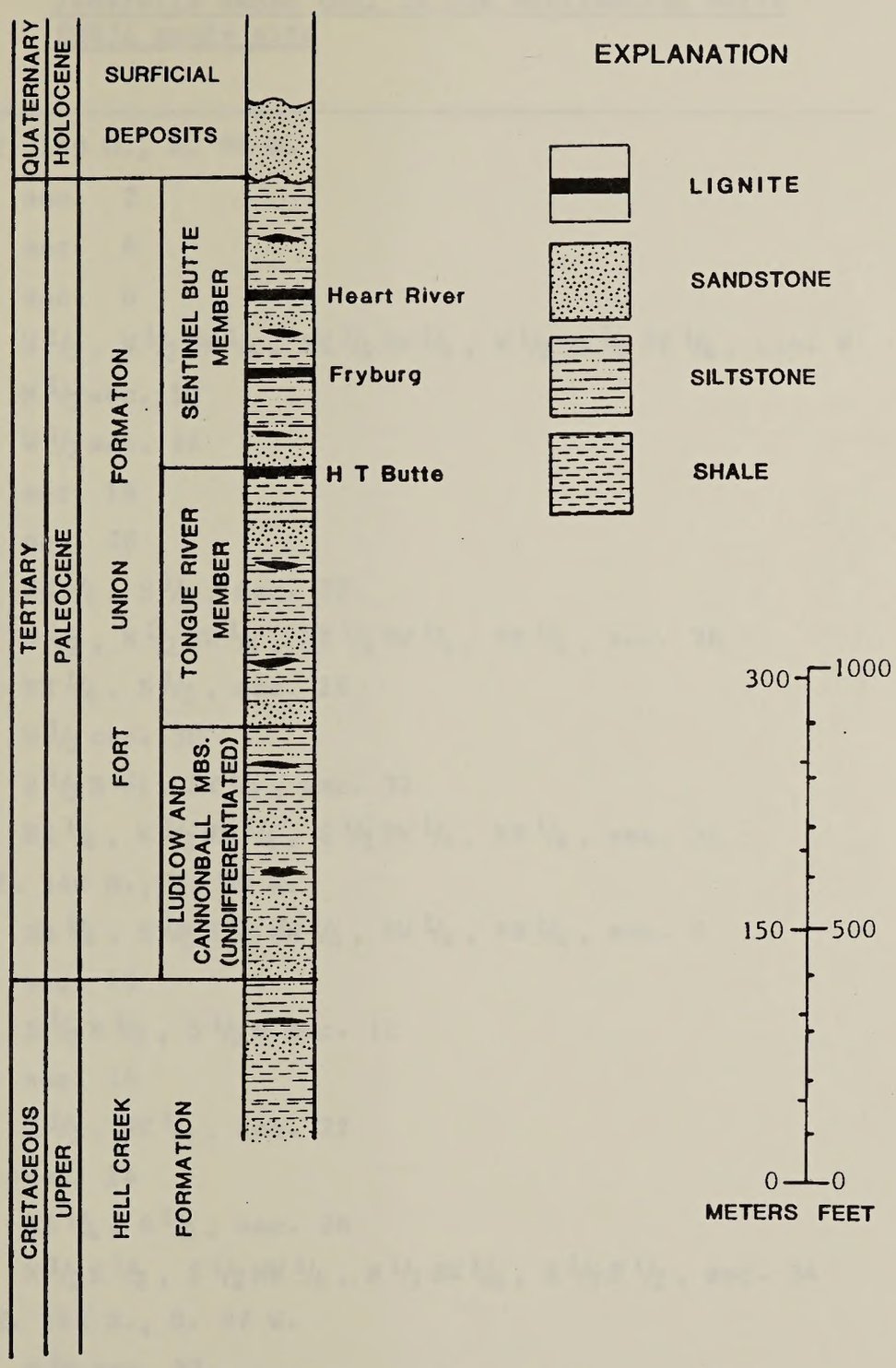


Fig. 3 --Generalized stratigraphic section, Rattlesnake Butte EMRIA study site, Dickinson coal field, North Dakota (modified from Menge, 1978)

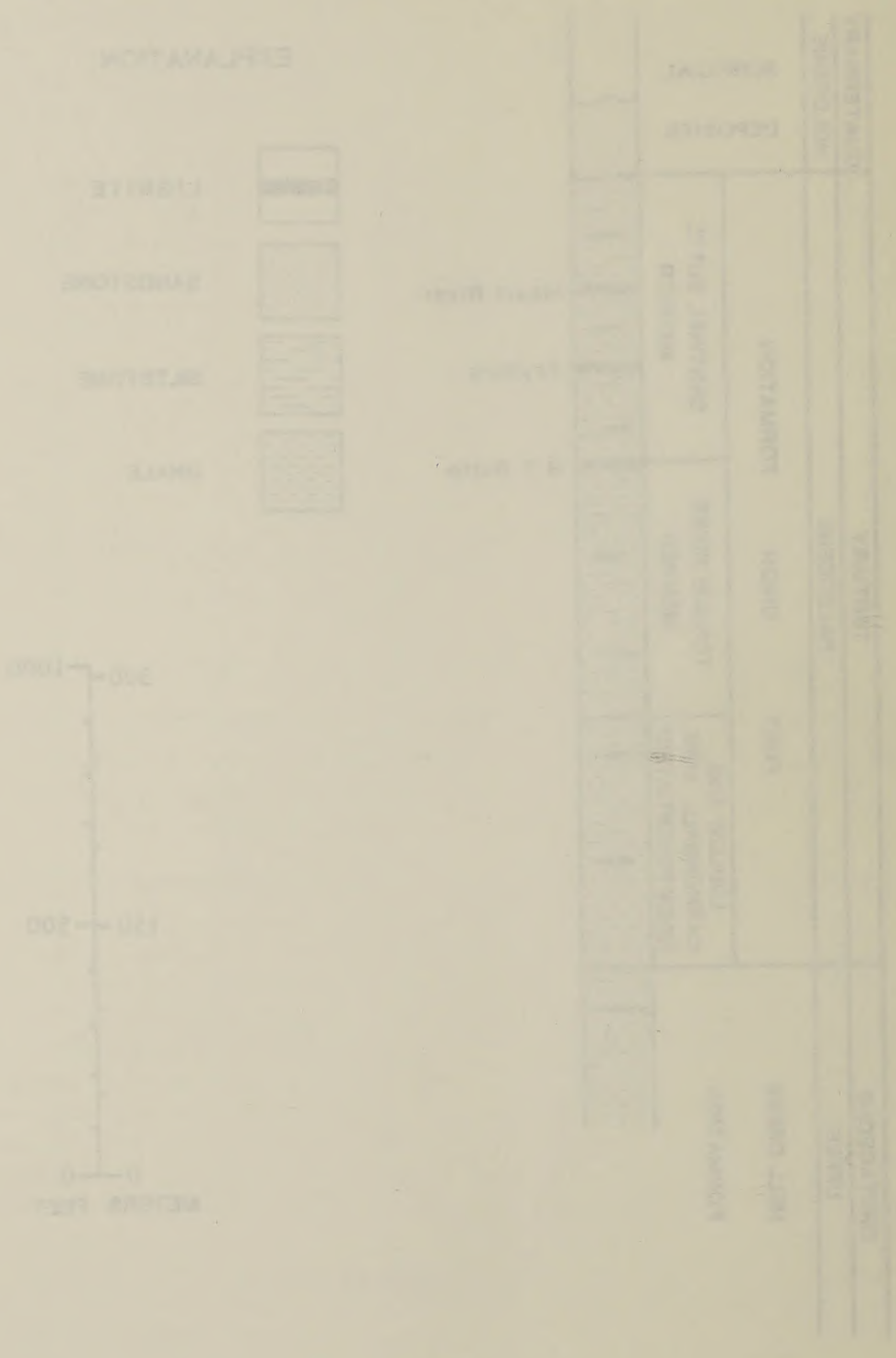


Table 6--Legal description of land underlain by Federally owned coal in the Rattlesnake Butte EMRIA study site

T. 140 N., R. 98 W.
sec. 2
sec. 4
sec. 6
N 1/2, W 1/2 SW 1/4, SE 1/4 SW 1/4, W 1/2 SW 1/4 SE 1/4, sec. 8
N 1/2 sec. 10
W 1/2 sec. 14
sec. 18
sec. 20
NW 1/4, S 1/2, sec. 22
N 1/2, N 1/2 SW 1/4, SE 1/4 SW 1/4, SE 1/4, sec. 26
NE 1/4, S 1/2, sec. 28
W 1/2 sec. 30
S 1/2 N 1/2, SW 1/4, sec. 32
NE 1/4, N 1/2 NW 1/4, S 1/2 SW 1/4, SE 1/4, sec. 34

T. 140 N., R. 99 W.
NE 1/4, S 1/2 S 1/2 NW 1/4, SW 1/4, SE 1/4, sec. 2
sec. 10
S 1/2 N 1/2, S 1/2 m sec. 12
sec. 14
N 1/2, SE 1/4, sec. 22
sec. 24
NE 1/4, S 1/2, sec. 26
N 1/2 N 1/2, S 1/2 NW 1/4, N 1/2 SW 1/4, S 1/2 S 1/2, sec. 34

T. 141 N., R. 97 W.
W 1/2 sec. 32

T. 141 N., R. 98 W.
S 1/2 SW 1/4 sec. 26
sec. 32
NE 1/4, SE 1/4, sec. 34

Table 7--Chemical analyses of 19 lignite samples from the Rattlesnake Butte EMRIA study site

[All analyses are in percent except Btu/lb; to convert feet to meters multiply by 0.305; to convert Btu/lb to Kcal/kg multiply by 0.556.]

Laboratory number	Coal bed name	Drill hole number	Depth interval feet	Proximate				Ultimate	Btu/lb (as-received)
				Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	
K99744	Heart River	112-1	34.3- 38.9	42.6	27.0	24.9	5.5	0.4	6216
K99745	Fryburg	112-2	138.5-145.0	40.9	22.3	23.8	13.0	.3	5316
K99746	Heart River	111-1	20.3- 28.7	45.0	23.2	26.0	5.8	.5	5738
K99747	Local	111-2	125.9-129.7	35.7	20.6	17.8	25.9	.8	4566
K99748	Fryburg	111-3	159.0-165.9	40.7	24.3	25.4	9.6	1.3	5911
K99749	Local	109-1	25.8- 29.5	40.4	23.9	21.5	14.2	2.6	5292
K99750	Heart River	109-2	57.5- 68.5	45.7	23.6	24.6	6.1	.5	5708
K99751	Fryburg	109-3	116.1-119.7	43.9	23.0	24.1	9.0	.9	5607
K99752	Heart River	107-1	138.7-149.3	45.1	23.5	25.7	5.7	.5	5825
K99753	Fryburg	107-2	181.1-183.5	39.2	21.8	21.8	17.2	1.1	5199
K99754	Fryburg	107-3	187.2-194.7	41.5	21.1	23.3	14.1	3.0	5210
K99755	Heart River	110-1	64.8- 74.8	44.8	24.0	25.2	6.0	.8	5832
K99756	Fryburg	110-2	136.2-149.0	41.5	22.7	23.8	12.0	.7	5505
K99757	Fryburg	114-1	90.5- 94.6	39.0	23.6	22.6	14.8	1.7	5508
K99758	Heart River	106-1	90.5-108.2	43.7	23.1	26.3	6.9	.6	5845
K99759	Fryburg	106-2	198.7-208.2	39.6	22.9	26.0	11.5	.4	5790
K99760	Heart River	102-1	48.2- 53.2	41.1	25.3	24.5	9.1	2.6	5749
K99761	Fryburg	102-2	139.5-149.6	42.7	24.5	23.9	8.9	.8	5725
K99762	Local	102-3	159.9-164.3	43.1	24.3	26.1	6.5	.4	5903
Heart River range				41.1-47.7	23.1-27.0	24.5-26.3	5.5-9.1	0.4-2.6	5708-6216
Heart River average				44.3	24.2	25.3	6.4	.8	5845
Fryburg range				39.0-43.9	21.1-24.5	21.8-26.0	8.9-17.2	.3-3.0	5199-5911
Fryburg average				41.0	22.9	23.9	12.2	1.1	5530
Range of 19 samples				35.7-45.7	20.6-27.0	17.8-26.3	5.5-25.9	0.3-3.0	4566-6216
Average of 19 samples				41.9	23.4	24.1	10.6	1.0	5602

Density

The density of the coal ranges considerably with differences in rank and ash content. In areas such as the Rattlesnake Butte EMRIA study site, where true density of the coal has not been determined, an average density based on many determinations in other areas is used to express the density of the coal for resource calculations. The average density of this lignite is assumed to be 1750 tons per acre-foot, and the specific gravity is 1.29.

Thickness of Beds

Because of the important relationship of coal-bed thickness to utilization potential, most coal resource estimates prepared by the U.S. Geological Survey are tabulated according to three thickness categories. The thickness categories used for lignite are thin 2.5 to 5 feet (0.75 to 1.5 m); intermediate 5 to 10 feet (1.5 to 3 m); and thick more than 10 feet (3 m). About 32% of the estimated resources of the study area is in the thick category, about 56% is in the intermediate category and 12% is in the thin category. By way of comparison, Averitt (1975, fig. 5 and p. 37) showed the distribution of the estimated resources of 21 states as 42 percent in the thin category, 25 percent in the intermediate category, and 33 percent in the thick category.

Thickness of Overburden

All of the estimated lignite resources in the Rattlesnake Butte EMRIA site are overlain by less than 300 feet (91 m) of overburden.

Estimation and Classification of Coal Resources

Coal resource estimates have been prepared for the Fort Union coal within the Rattlesnake Butte EMRIA study site using standard procedures, definitions, and criteria established by the U.S. Bureau of Mines and U.S. Geological Survey (1976) for making coal resource appraisals in the United States. The term "coal resources" as used in this report means the estimated quantity of coal in the ground in such form that economic extraction is currently or potentially feasible.

Tabulation of estimated coal resources

Tables 8-20, Appendix C, summarize the estimated lignite resources of the Rattlesnake Butte EMRIA study site. The resources in the study site are classed as measured, indicated, and inferred according to the degree of geologic assurance of the estimate.

Measured - Resources are computed from thicknesses revealed in outcrops, trenches, mine workings, and drill holes. The points of observation and measurement are so closely spaced and the thickness and extent of coals are so well defined that the tonnage is judged to be accurate within 20 percent of true tonnage. Although the spacing of the points of observation necessary to demonstrate continuity of the coal differs from

region to region according to the character of the coal beds, the points of observation are no greater than ½ mile (0.8 km) apart. Measured coal is projected to extend as a ¼ mile (0.4 km) wide belt from the outcrop or points of observation or measurement.

Indicated - Resources are computed partly from specific measurements and partly from projections of visible data for a reasonable distance on the basis of geologic evidence. The points of observation are ½ (0.8 km) to 1 ½ miles (2.4 km) apart. Indicated coal is projected to extend as a ½ mile (0.8 km) wide belt that lies more than ¼ mile (0.4 km) from the outcrop or points of observation or measurement.

Inferred - Quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region, because few measurements of bed thickness are available. The estimates are based primarily on an assumed continuation from measured and indicated coal for which geologic evidence exists. The points of observation are 1½ (2.4 km) to 6 miles (9.6 km) apart. Inferred coal is projected to extend as a 2¼-mile (3.6 km) wide belt that lies more than 3/4 mile (1.2 km) from the outcrop or points of observation or measurement.

Summary of Resources

Total estimated identified lignite resources in the Rattlesnake Butte EMRIA site are 484 million tons (439 million metric tons). Of this amount, 58.3 million tons (52.9 million metric tons) are in beds 2.5-5 feet thick, 269 million tons (244 million metric tons) are in beds 5-10 feet thick, and 156 million tons (141 million metric tons) are in beds more than 10 feet thick. Measured resources total 55.7 million tons (50.0 million metric tons), indicated resources total 233 million tons (211 million metric tons) and inferred resources total 196 million tons (178 million metric tons).

The estimated resources presented in this report are original resources; that is; resources in the ground before the beginning of mining operations.

Principal Soil Bodies*

Soils of the Rattlesnake Butte Study Area can be placed in two major categories based on their mode of development, landform position, and parent material. They are: (1) residual soils on uplands developing in weathered sandstone, siltstone, shale, and baked shale (scoria), and (2) alluvial/colluvial soils on fans, footslopes, swales, and terraces forming in loamy alluvial/colluvial deposits. The soft sedimentary strata of the Fort Union Formation (Sentinel Butte Member) have provided the parent materials for both major soil categories. The residual soils occur over approximately 85 percent of the area. The alluvial/colluvial soils occupy about 10 percent of the area; minor soil inclusions (i.e., wind-deposited soils) occur on only 5 percent of the area.

Four types of residual soils were identified on the basis of their parent material and textural composition. These are: (1) moderately coarse and coarse-textured soils developing over soft sandstone, (2) medium-textured soils forming over siltstone and silty shale, (3) medium-textured soils developing over baked shale, and (4) moderately fine to fine-textured soils forming over shale.

The moderately coarse and coarse-textured residual soils developing over softly consolidated sandstone occupy gentle to steep upland slopes. The depth of these soils is variable, ranging from less than 10 inches (.25 m) to more than 60 inches (1.5 m). The surface horizon of these soils is typically a very friable, very dark grayish brown fine sandy loam. The subsurface horizons grade from dark brown fine sandy loam to pale yellow soft sandstone. Permeability is moderately rapid in these soils and moisture retention appears adequate to support the growth of native range plants or adapted crops. The surface layer is usually noncalcareous, whereas the subsurface layers are moderately to strongly calcareous. These soils are nonsaline and nonsodic. Due to their textures, these soils may be highly susceptible to wind and water erosion, especially on steep slopes and in areas of sparse vegetative cover.

In general, these soils should provide a plentiful source of fair to good quality material for revegetation. However, selective stripping of these soils on steep slopes may be difficult.

The Point Site profile described in Table 21, Appendix D, is representative of this soil type.

The medium-textured residual soils forming over siltstone and silty shale occur in upland areas on gentle to steep slopes. Soil depth is closely related to landform position, with shallow soils (less than 10 inches - .25 m) occurring on steep slopes and deep soils (more than 60 inches - 1.5 m) occupying gentle slopes. The surface horizon is typically a friable, very dark grayish brown silt loam. The subsurface horizons grade from dark gray silt loam to olive gray silty clay loam. Permeability is usually moderate in the surface horizon and moderately slow in the finer-textured subsurface

*All soil colors described are for moist samples.

horizons. Available moisture for plant use is moderately high. Generally, the surface layer is noncalcareous, whereas the subsurface and substratum are moderately to strongly calcareous. The surface layer is usually nonsaline; the subsurface layers are moderately to strongly saline.

The surface layer of these soils will provide an adequate supply of good quality revegetative media. Due to their fine texture and salinity, the subsurface layers should be replaced below the plant rooting zone in reconstructed profiles. Selective stripping of the surface layer on steep slopes may be difficult.

The Point Site profile described in Table 22, Appendix D, is representative of this soil type.

The medium-textured residual soils developing over baked shale occur on gentle and moderate slopes in upland areas. These soils are very shallow to shallow over fractured bedrock (depth varies from 3 to 18 inches - .08-.46 m). The surface layer is commonly a friable, dark brown loam. The subsurface layers grade from reddish brown, channery loam to yellowish red, fractured bedrock (scoria). Water readily infiltrates and percolates through these soils. The available moisture retained for plant use is moderately low. Generally, the surface layer is noncalcareous; the subsurface layers and substratum are slightly calcareous. These soils are nonsaline and nonsodic. These soils may be highly susceptible to erosion, especially in areas lacking an adequate vegetative cover.

The overall quality of these soils as a revegetative medium is fair. The quantity of available material will be limited due to the shallow nature of these soils. Because of their shallowness, stripping operations may be difficult.

The moderately fine to fine-textured residual soils forming over shale occupy nearly level to steeply sloping uplands. These soils vary in depth from less than 10 inches (.25 m) to more than 30 inches (.76 m) over alkaline shale. The surface horizon is typically a friable, brown silty clay loam. The fine-textured subsurface horizons are commonly grayish brown to dark grayish brown silty clay loam to silty clay. Water infiltrates these soils at a slow rate, resulting in excessive runoff and erosion, especially in steeply sloping and sparsely vegetated areas. Permeability of these soils is also slow, especially in the subsurface layers and substratum. The available water retained in the root zone is moderately high. Generally, the surface horizon is slightly calcareous and the subsurface horizons and substratum are moderately to strongly calcareous. The surface layer is slightly to moderately saline; the subsurface layers and substratum are moderately to strongly saline.

The surface layer of these soils appears suitable for use as topsoiling material. Because of their fine texture and salinity, the subsurface layers and substratum should be replaced below the plant rooting zone in reconstructed profiles. Selective stripping of the surface layer in steep, hilly areas may be difficult.

The Point Site profile described in Table 23, Appendix D, is representative of this soil type.

The alluvial/colluvial soils in this study area were subdivided into three groups on the basis of landform position, period of deposition, and physical/chemical characteristics. These are: (1) young alluvial/colluvial soils developing in recent deposits on gently sloping fans and footslopes and in the bottom and adjacent to intermittent streams, (2) mature alluvial/colluvial soils forming in ancient deposits on gently to moderately sloping upland terraces and footslopes, and (3) alkaline alluvial/colluvial soils developing in sodium-affected deposits on gently sloping terraces and footslopes.

The young alluvial/colluvial soils are usually moderately deep and well drained. Soil textures are variable, ranging from loam to loamy sand. Typically, the surface horizon is friable and dark gray to dark grayish brown in color. Colors of the subsurface layers and substratum are highly variable, depending on the nature of the deposits. Permeability is moderate to moderately rapid, depending on the textures. Available moisture for plant use ranges from moderate in the loamy soils to moderately low in the coarser-textured soils. These soils are nonsaline and nonsodic. The surface and subsurface horizons are usually noncalcareous, whereas the substratum is moderately to strongly calcareous. Erosion of these soils is usually not a significant problem due to their stable landform position. However, the coarser-textured soils may be moderately susceptible to wind and water erosion on lands lacking an adequate vegetative cover.

In general, the depth and favorable physical/chemical properties of these soils will make them an excellent source of good to high quality revegetative material. Stripping operations should not be difficult.

The mature alluvial/colluvial soils are typically deep and well drained. Soil textures range from medium to moderately coarse, depending on the nature of the deposits. Generally, the surface layer is very friable, dark grayish brown, and medium-textured. The colors and textures of the subsurface layers and substratum are highly variable. Infiltration and permeability are moderately rapid in these soils. The available moisture retained for plant use is moderate to moderately low. Generally, the surface and subsurface horizons are noncalcareous to slightly calcareous and the substratum is strongly calcareous. These soils are nonsaline and nonsodic. Erosion of these soils, especially by wind, may be significant on moderate slopes and in sparsely-vegetated areas.

These soils represent an abundant source of good to high quality topsoiling material for revegetation. Stripping operations should not be exceedingly difficult.

The Point Site soil profiles in Tables 24 and 25, Appendix D, are representative of this soil group.

The alkaline alluvial/colluvial soils are generally deep. The surface horizon is typically very friable, dark grayish brown to brownish gray, and medium-textured. The subsurface horizons are usually grayish brown

and moderately fine-textured. Columnar structure is common in the subsurface horizons. Permeability is moderate in the surface layer and moderately slow in the subsurface layers and substratum. The available moisture retained for plant use is moderately high. The profiles are generally noncalcareous in the surface horizons and upper part of the subsurface horizons and strongly calcareous in the lower part of the subsurface horizons and substratum. The surface layer is usually slightly saline and moderately alkaline; the subsurface layers and substratum are strongly saline-sodic (strongly alkaline). The topography of lands occupied by these soils is often characterized by a predominance of microdepression "slick spots" which may be partially void of vegetation. These areas may be highly susceptible to erosion.

An abundant supply of revegetative material will be available from this soil group. However, the highly saline/alkaline nature of these soils will limit their use to below the plant rooting zone in reconstructed profiles unless the material is modified by chemical amendments (i.e., gypsum), leaching, etc.

The Point Site soil profiles in Tables 26 and 27, Appendix D, are representative of this soil group.

Land Suitability Classification

A semidetailed land suitability classification of the Rattlesnake Butte Study Area was made to evaluate and characterize the overburden (includes soil/bedrock to a depth of 10 feet)[1/] as a source of material for resurfacing and revegetating the area if it is surface-mined. This survey provides data on the quantity and quality of material for revegetation and ease of stripping and stockpiling the usable material.

Land suitability specifications, shown on Table 28, were developed to establish classes for the specific use proposed, i.e., as a source of material for revegetation of surface-mined land. Four land classes: 1, 2, 3, and 6 were developed. These correspond to classes used in the Bureau of Reclamation land classification system.

Factors included in the specifications for quality consideration were: texture, salinity, sodicity, hydraulic conductivity, erodibility, available water holding capacity, and percentage of coarse fragments (i.e., cobble) in the soil mass. Quantity considerations were based primarily on the depth of the material. Other factors influencing the ease with which suitable material could be selectively stripped and stockpiled were also considered. These included steep, rough, or complex slopes, and percentage of rock cover (i.e., clinker) on the surface.

Class 1 lands provide the most desirable and plentiful source of soil material for revegetation. An abundant supply of highly suitable material, which is easily stripped and stockpiled, will be available from this land class. In addition to having an adequate amount of suitable material for reclaiming the immediate area, Class 1 lands can probably

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1/ A glossary defining terms is included in Exhibit 4, Appendix D.

LAND SUITABILITY SPECIFICATIONS - SURFACE MINE RECLAMATION
Suitability of Overburden for Revegetation of Surface-Mined Areas
BLM/WPRS Cooperative Program - EMRIA
Rattlesnake Butte Study Area

Table 28
United States
Dept. of the Interior
Bureau of Reclamation
July 1978

Overburden Characteristics	Symbols: Basic Subclass	Symbols: Information and Deficiencies	Class 1	Class 2	Class 3
SOILS AND/OR BEDROCK	s				
Textures			Fine sandy loams to clay loams	Sandy loam to silty clay loams	Loamy sand to clay
Coarse		v		Sandy loam or gravelly material sufficiently coarse to slightly reduce productivity and moisture retention	Loamy sand or gravelly material in sufficient quantity to moderately reduce productivity and moisture retention
Fine		h		Profile should have sufficient material for topdressing; clayey materials that are slowly permeable should be placed below 18" in the reconstructed profile	Profile should have sufficient material for topdressing; placement of clay should be below 10" in the reconstructed profile; material objectionable to plant roots should be placed below root zone
Depth		d	>36" of overburden that is suitable for plant media	>18" of overburden that is suitable for plant media	>10" of overburden that is suitable for plant media
Sodicity		a	SAR not to exceed 9.0 in fine-textured soils, but may be up to 20.0 in soils with loamy sand textures. Values can be slightly higher if compensated by adequate residual gypsum.		
Salinity ($ECx10_3$)		s	Less than 4	Less than 8 but should have 10" of material of less than 4 for surface	Less than 12 but should have 10" of material of less than 4 for surface
Available Water Holding Capacity		q	>1.5"/foot of soil	>1.0"/foot of soil	>0.75"/foot of soil
Hydraulic Conductivity		p	Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion	Slightly restricted which may result in some restriction of drainage and aeration in the root zone and a reduced infiltration rate	Restricted to the extent that internal drainage may limit choice of vegetation and require special practices to control erosion.
Cobbly, Stony, Flaggy, or Clinkers		x	Less than 5% in soil mass	Less than 10% in soil mass	Less than 20% in soil mass
Weatherability[1/]			Will break down readily upon exposure to the weather	May require short period to break down upon exposure	May require extended period to break down
Erodibility			Susceptible to slight erosion	Susceptible to moderate erosion	Susceptible to severe erosion but can be controlled with proper management and placement
TOPOGRAPHY[2/]	t				
Slope		g	Permissible surface gradient 0 to 12 with smooth slopes	Permissible surface gradient 0 - 20%: undulating to complex slopes	Permissible surface gradient 0 - 35%; hilly to steep slopes
Cobbly, Stony, Flaggy, or Clinkers		r	None	1 to 5% of surface area	5 to 20% of surface area
Cover		c	Not applicable		
DRAINAGE	d		Because of anticipated land alterations by surface mining, present drainage conditions, except the hydraulic conductivity of the material, are not a factor in the classification.		

Class 6

Areas delineated in this class generally lack suitable material for stripping and stockpiling as surface material. One or a combination of the following deficiencies may result in the use of this class: (1) insufficient surface soil and bedrock of suitable quality at or near the surface; (2) topography which prevents stripping including excessive slopes; (3) rocklands with large amounts of massive indurated surface sandstone; (4) toxic overburden (soil and bedrock), on or near the surface. Reclamation of Class 6 lands will require that suitable plant growth material be borrowed from adjacent lands that have a surplus of good quality planting media or from suitable bedrock strata. In certain cases, treatment or modification of the available material may increase its revegetative potential to an acceptable level.

1/ Applicable only to bedrock material.
2/ Not applicable to bedrock material.

provide borrow material for topdressing areas with insufficient suitable material. Class 2 lands contain an adequate supply of resurfacing material to revegetate the immediate area; however, this material is slightly less desirable in quality or somewhat more difficult to strip and stockpile than the material on Class 1 lands. Class 3 lands are similar to those in Class 2, except the deficiencies are more pronounced or a combination of deficiencies exists. Land in this class is marginally suitable for revegetation but, through utilization of good stripping and stockpiling procedures, the requirements for planting media can generally be met. Class 6 lands lack adequate quantities of suitable material to meet the needs for revegetation. If these lands are disturbed by surface mining, it will be necessary to borrow material from Class 1 or 2 lands or modify the material available for revegetation through leaching, addition of chemical amendments, etc.

Table 29 expands the preceding summary description of the land classes and describes the significant characteristics of the major land classes and subclasses.

The land suitability classification was acccomplished using Bureau of Reclamation methods and procedures. Field mapping was done on aerial photographs with a scale of 1:12,000. Topographic drawings at a scale of 1:24,000 with 20-foot contour intervals were used for reference. An Abney hand level was used in the field to supplement the slope data on the topographic drawings.

Representative (Point Site) soil profiles typical of extensive areas of Class 1, 2, 3 and 6 lands were described, sampled, and analyzed in detail. Additional profiles were recorded in the heterogeneous soil areas to show variations within the delineated areas. This information was supplemented by nonrecorded profile examinations as required. Nonrecorded profiles are typically located in transitional areas between soil types to more accurately locate boundaries.

In the field appraisal, the top 16 inches of the soil profiles were exposed with a tile spade. A hand auger or hydraulic coring machine was then used to penetrate the overburden to a depth of 10 feet unless hard bedrock was encountered. Soil structure, texture, consistence, color, and other observable features of the exposed profile such as salinity, sodicity, and root distributions were recorded. Lime content was checked with dilute hydrochloric acid. Samples were collected from many of the exposed profiles. Evaluation of the soil material for hydraulic conductivity and available water holding capacity in relation to the reclaimed profile was a major consideration in the field evaluation. Using these basic soil evaluations, along with observations of other land features such as surface rock cover and slope, a land suitability class was tentatively assigned each delineated area while in the field. The suitability classes, when finalized, were recorded on land classification maps, Plates 29 through 37.

A soil laboratory was used in connection with the land suitability classification and screenable tests were performed on all soil samples. These tests included disturbed hydraulic conductivity, salinity, pH, and moisture retention (15 bars). More detailed soil analyses were then made as required. Exhibit 1, Appendix D, describes the screenable testing procedures used in the laboratory.

Complete soil analyses were performed on all samples from Point Site profiles representative of the major categories in the land suitability classification. The analyses listed in Exhibit 2, Appendix D, were performed as needed for proper overburden evaluation.

Results of Land Suitability Classification

The results of the land suitability classification are recorded graphically on semidetailed drawings, Plates 29 through 37 which show the areal distribution of the various land classes, soil deficiencies, topographic deficiencies, profile notes of soil borings, and the results of laboratory analyses. This information is also summarized on Plates 38 through 55. Plates 38 through 46 describe the location and depth of material that is suitable for use at or near the surface in reconstructed profiles. Plates 47 through 55 indicate the location and quality of material that is suitable for subsurface placement in reconstructed profiles.

Table 30 lists the acreage of each land class occurring in this study area. The results in this table indicate that 97.4 percent of the land in the Rattlesnake Butte Study Area contains an adequate quantity of suitable overburden (soil and/or bedrock to a 10-foot depth) to restore the disturbed area to a condition capable of supporting the present uses. This includes Class 1, 2, and 3 lands. The remaining 2.6 percent of the study area, designated as Class 6, will require borrowed soil/bedrock material from Class 1 or 2 lands or modification of the available material (i.e., chemical amendments, leaching, etc.) in order to provide adequate plant media for revegetation.

This land suitability classification provides adequate data for developing the reclamation portion of the mining plan; however, it does not provide adequate detail for stripping and stockpiling procedures during the surface mining operation. Additional field borings and observations, supported by laboratory data, will be required to more accurately determine the quantity, quality, and location of material to be stripped and stockpiled for use as revegetative media.

Overburden Suitability for Revegetation

Soil Mantle Suitability

Based on the field and laboratory data obtained from the land suitability classification, it appears that most of the residual and alluvial/colluvial soils in this study area should yield about 6 to 12 inches (.15 - .30m) of good quality topsoiling material for revegetation (see Plates 38 through 46). This material, which usually includes the A and upper portion of the B horizons, is typically nonsaline, nonsodic, and permeable. Because the A horizon of most soils in the study area is only 2 to 6 inches (.05 - .15m) thick, selective stripping of this horizon from the B horizons seems impractical. However, mixing of the A and upper portion of the B horizons should not appreciably change the overall quality of the material.

Many of the soil profiles showed a marked increase in soluble salts, exchangeable sodium, and/or clay content below 12 to 18 inches (.30 - .46m) in depth. Therefore, a significant percentage of the available subsurface

Sec. 28; T. 141N; R. 98W

1200'N., 100'E. of SW Cor.
0-.61m. preferred surface material. .61-1.3 acceptable for surface. 2-4% complex side slope. Salk crystals at .76m. Profile better than average. 30% slick spot influence in the area.

600'W., 100'N of SW1/4 Cor.
0-.15m. preferred surface material. .15-.45m. acceptable for surface. .45-1.5m. subsurface use. 0-2% complex colluvial bottom.

800'N., 400'W. of SE Cor.
0-.15m acceptable surface material. .15-.91m subsurface use. .91-3.0m for use below root zone. 2-4% complex side slope. Salt crystals at .45m. Area better than the indicated results.

700'S., 200'W. of E1/4 Cor.
0-.15m. acceptable for surface. .15-3.0m. for subsurface use. 0-2% complex colluvial bottom with salt influence in area. Salt accumulations at 1.3m. Sandy shale becoming more consolidated at 3.0m.
.45-.91m., SAR 7.8

100'E of W1/4 Cor.
0-.15m. preferred surface material. .15-.76m. acceptable for surface. .76-1.3m. subsurface use. 1.3-3.0m. for use below root zone. 2-4% complex side slope with 20% area degraded slick spots. Profile downgraded due to numerous slick spots.

Sec. 30; T. 141N; R. 98W

1500'E., 400'S. of W1/4 Cor.
0-.15m acceptable surface material. .15-1.3m subsurface material. 1.3-3.0m for use below root zone. 2-4% complex side slope. Salt crystals at .91m.

700'S., 350'S. of N1/4 Cor.
0-.45 preferred surface material. .45-1.9m subsurface material. 1.9-3.0m for use below root zone. 0-2% complex colluvial bottom with 50% vegetated slick spots. .76m weathered shales with salt crystals. 1.2-2.1m soft sandy shales. 2.4-3.0m sandy shales with thin clayey stratifications.

1400'W., 400'N. of E1/4 Cor.
0-.15 acceptable surface material. .15-.76m. subsurface use. .76-3.0m. for use below root zone. 2-4% complex side slope on gentle high area. Residual profile over weathered shale at .45m. Salt crystals at .76m. .05-.67m., SAR 10.0

1300'E. of W1/4 Cor.
0-.45m. preferred surface material. .45-1.2m. acceptable for surface. 1.2-2.1m. subsurface material. 2.1-3.0m. for use below root zone. 0-2% complex colluvial bottom with alkali influence in the area. Salt crystals at .76m. 1.2-1.6m., SAR 8.5

1800'E., 1100'S. of W1/4 Cor.
0-.15m preferred for surface. .15-.91m acceptable for subsurface use. .91-1.8m for subsurface use. 4-8% complex side slope. Salt crystals at .30m. Shallow to shales in area.

700'N., 300'E. of W1/4 Cor.
0-.15m acceptable for surface. .15-2.1 subsurface material. 2.1-3.0m for use below root zone. 2-4% complex side slope. Weathered shales at .45m with salt crystals at .76m. Heavy dark organic influenced clayey shales at 1.5m. Baked shales at 2.7m.

700'E. of N1/4 Cor.
0-.15m. acceptable for surface. .15-1.2m. subsurface use. 1.2-3.0m. for use below root zone. 2-6% complex side slope with strong slick spot area influence. .45-.61m. weathered sandy shale weakly calcareous. .61m. semi-consolidated sandy shale. Salt crystals .61m. .30-.61m., SAR 5.5

1100'E. of NW Cor.
0-.15m. acceptable surface material. .15-.76m. for subsurface use. .76-3.0m. for use below root zone. 0-2% complex area with slick spots influence. Weathered sandy shale from .30-.76m. Oxidized sandy shale 1.3m. Salt crystals at .36m. .30-.76m., SAR 7.6 1.3-1.9m., Gyp +9.2

1900'E., 700'S. of W1/4 Cor.
0-.15m acceptable surface material. .15-3.0m for subsurface use. 2-4% complex colluvial bottom. Salt crystals at .61m. Surface material for deleniated area better than indicated.

Sec. 32; T. 141N; R. 98W

900'N., 100'E. of SW Cor.
0-.45m. preferred surface material. .45-.91m. acceptable for surface. .91-3.0m. subsurface use. 2-6% complex wind deposited surface side slope. 1.8m. material stratified LFS/FS. Effective depth varies being shallower on high areas. Profile better than average.

1200'N., 800'E. of W1/4 Cor.
0-.30m. acceptable surface material. .30-1.5m. subsurface use. 1.5-3.0m. for use below root zone. 2-4% side slope with slick spots in the area. .45-.61m. C_{cs} weathered shales. .30-.61m., SAR 11.1

1200'E., 100'S. of N1/4 Cor.
0-.30m. acceptable surface material. .30-.91m. subsurface use. .91-3.0m. for use below root zone. 0-2% complex foot slope with slick spots in area. Oxidized shale 1.5m. Sandstone erratics at 2.1m. Salt crystals at .30m.
Depth =; SAR =; Gyp =.
.30-.91=, —=; =2.0
.91-1.5=, =2.0-=3.5
1.5-2.1=, =3.5-=4.6

700'E., 200'S. of NW Cor.
0-.15m acceptable surface material. .15-3.0m for subsurface use. 4-8% complex bench remnant. Salt crystals at 1.5m. Area shows influence of baked shales and water by gravel caps/remnants.

500'E., 2000'N of S1/4 Cor.
0-.15m. acceptable surface material. .15-.15m. for subsurface use. .15-3.0m. for use below root zone. 2-4% complex foot slope with salts outcroping on surface in area. Salt accumulations at .30m. Free water at 2.1m. .30-.91m., SAR 8.5

700'N., 400'E. of W1/4 Cor.
0-.15m. acceptable surface material. .15-.45m. subsurface material. .45-3.0m. for use below root zone. 0-2% complex foot slope with slick spots in area. Free water at 2.1m. Salt crystals at .15m.

1100'W., 200'N of SE Cor.
0-.45m. preferred surface material. .45-1.1m. acceptable for surface. 1.1-2.2m. subsurface use. 4-6% complex side slope. Profile better than average.

900'N., 200'W. of E1/4 Cor.
0-.15m acceptable for surface use. .15-3.0m for use below root zone. 2-4% complex bench remnant shallow to heavy shales. Crusty surface over weathered shale and salt crystals to 1.5m. Semi-consolidated shales at 1.5m. Shale outcroping in the area.

1100'W., 300'N of SE Cor.
0-.15 acceptable surface material. .15-3.0m. subsurface material. 2-4% complex foot slope. >SCL C_{cs}. Weathered shale from .15-.76m. Salt more prominent 1.1m. .45-.76m., SAR 7.7

* EXPLANATION

LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant media deficiency; Topographic deficiency; Informative symbols

SURFACE LAYER — Quality; Depth

SECOND LAYER — Quality; Depth

Divides soil material and nonsoil material

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES
(for plant media)

a Sodicity
s Salinity
h Clay (very fine texture)
v Coarse (very sandy texture)
p Restricted permeability
q Available moisture capacity
d Depth of suitable overburden
x Cobbly, stony, flaggy or clinkers (soil profile)

TOPOGRAPHIC DEFICIENCIES

g Slope (including gradient and complexity)
r Cobbly, stony, flaggy or clinkers (land surface)
c Cover

SOIL PROFILE NOTES

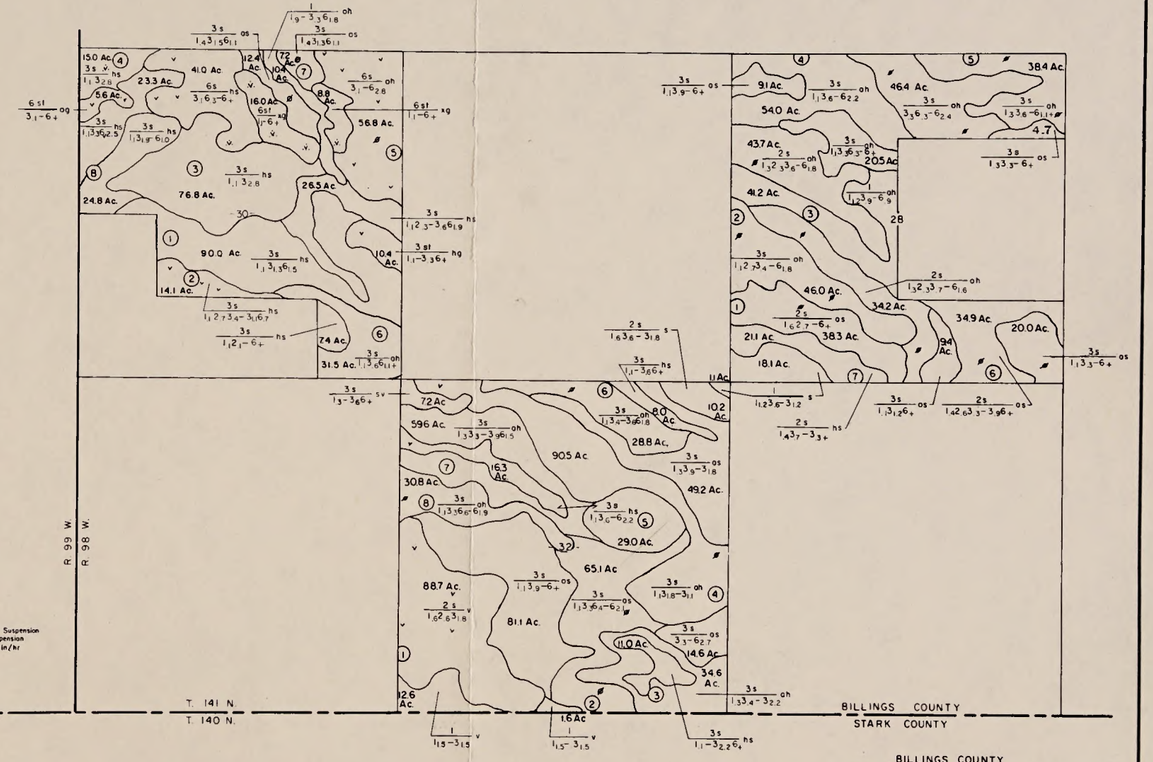
PROFILE REPRESENTS 30MMDEPTH
SOIL PROFILE NUMBER

C L — 2.8- --2.8 EC mmhos/cm Sat.Ext.
8.4-8.0 8.4 pH 1:5 Soil-Water Suspension
8.0 pH Soil-Ca Cl2 Suspension
.65 Hydraulic Conductivity in/hr (Disturbed Samples)
24 Settling Volume
Lf C
Gr

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lf	Light
M	Medium
H	Heavy

* Depths listed are in meters. Multiply by 3.28 to obtain feet.



1:12,000

BILLINGS COUNTY
SECTIONS 28,30,32 - T. 141 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCE SERVICE
RESOURCE & POTENTIAL RECLAMATION EVALUATION
DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T. FIECHTL — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — FEBRUARY, 1979 — SHEET 1 OF 9 — 1305-600-272

Sec. 26; T 141N; R. 98W

1 — 400'W., 200'N of SE Cor.
0-.19m acceptable for surface, .19-.61m subsurface use. .61-3.0m for use below root zone. 2-4% complex foot slopes with slick spot influence in area. Semi-consolidated sandy shale at 2.4m. .30-.61m, SAR 8.1

2 — 1300'W., 1000'N of SE Cor.
0-.15m acceptable for surface. .15-1.1m subsurface material. 1.1-3.0m for use below root zone. 0-2% complex colluvial bottom with slick spots. Salt crystals at 1.1m.

3 — 2000'W. of E1/4 Cor.
0-.15m preferred for surface use. .15-.45m acceptable surface material. .45-1.0m subsurface use. 2-4% complex colluvial foot slope with slick spots in area. Surface textures average for area excluding 10% slick spots in area. 1.1-1.0m, SAR 11.4

4 — 1200'E. of W1/4 Cor.
0-.30m acceptable for surface. .30-.61m subsurface material. .61-1.0m for use below root zone. 2-4% complex side slope with slick spots in area.

5 — 1200'W., 200'S. of NE Cor.
0-.25m preferred surface material. .15-.30m acceptable for surface. .30-3.0m subsurface use. 2-4% complex colluvial foot slope with slick spot influence. Areas within dellination containing higher percentage of slick spots. .76-1.2m, SAR 12.1

6 — 1100'W., 600'S. of W1/4 Cor.
0-.45m acceptable for surface. .45-.91 subsurface material. .91-3.0 for use below root zone. 0-2% complex colluvial swale with slick spots in area.

7 — 1200'E. of SW Cor.
0-.15m acceptable for surface. .15-.45m subsurface material. .45-3.0m for use below root zone. 2-4% complex foot slope with strong slick spot influence.
0-.45m, SAR 11.7

Sec. 34; T. 141N; R. 98W

1 — 500'E., 200'N. of SW Cor.
0-.30m preferred for surface. .30-.61m acceptable surface material. .61-1.2m subsurface use. 4-8% complex side slope with a residual baked shale surface. Bedrock outcropping as fractured rock in area. Shallower profiles in area. Class downgraded.

2 — 1200'S., 500'W. of E1/4 Cor.
0-.61m preferred surface material. .61-.91m acceptable for surface. .91-3.0m for subsurface use. 2-4% complex colluvial foot slope. 1.6-1.9m 40% fragments over 2mm. 1.9-2.4m, SAR 6.5 Profile better than average.

3 — 1300'W., 200'S. of E1/4 Cor.
0-.76m preferred surface material. .76-1.3m acceptable for surface. 1.3-3.0m for subsurface use. 2-4% complex foot slope below residual baked shale crests. Coal influencing material at 2.1m.

4 — 1300'W., 400'N. of E1/4 Cor.
0-.45m preferred surface material. .15-.45m acceptable for surface. .45-3.0m subsurface use. 0-2% complex colluvial bottom. Fragments of baked shale at 1.2m. Salt crystals at 1.2m.

5 — 700'W., 100'S. of NE Cor.
0-.15m acceptable for surface. .15-1.3m subsurface material. 1.3-3.0m for use below root zone. 2-4% complex foot slope with slick spots influencing area. Free water at 2.1 m. Salt crystals at .76m. .76-1.3m., SAR 7.5

6 — 1700'N., 200'E. of S1/4 Cor.
0-.15m acceptable for surface. .15-.45m subsurface material. .45-3.0m for use below root zone. 2-4% complex side slope with 6% slopes as minor inclusions. Sandstone influence in profile and area. Residual high areas are shallow to shale, .30-.76m., Gyp +3.2

* EXPLANATION

LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant media deficiency; Topographic deficiency; og — Informative symbols

SURFACE LAYER: Quality / Depth — 3 s1 s2 s3 s1 — 2.0 Quality / Depth

SECOND LAYER: Quality / Depth

Divides soil material and nonsoil material

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Cobbly, stony, flaggy or clinkers (land surface)
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 30IMDEPTH

3 SOIL PROFILE NUMBER

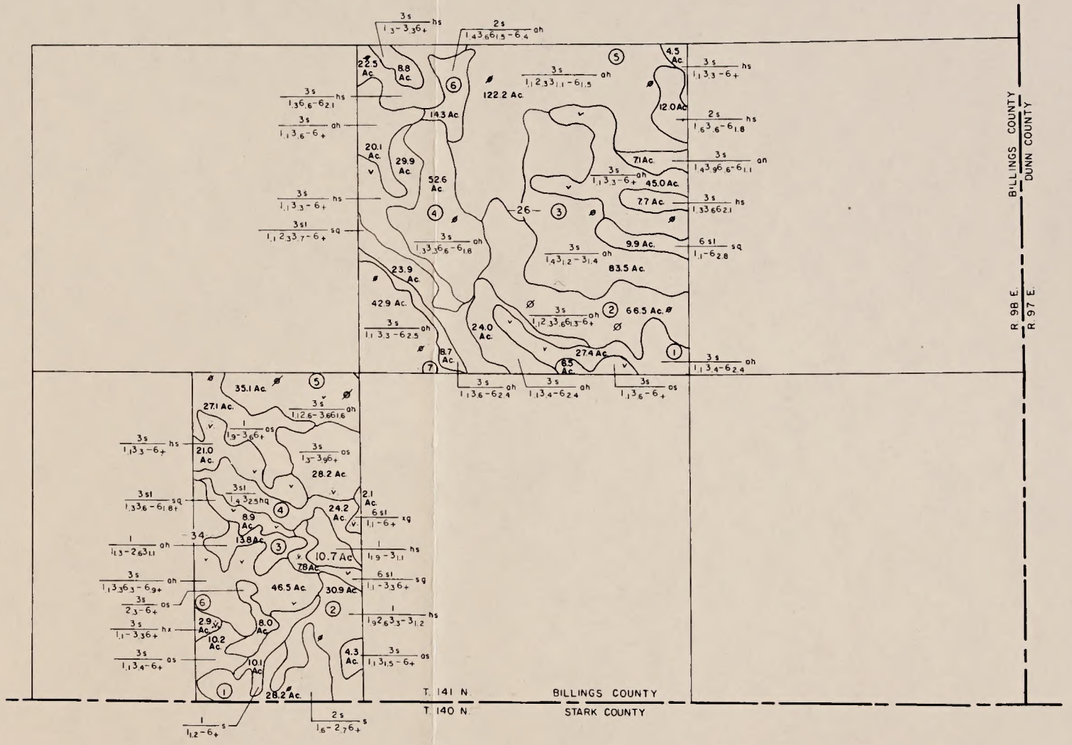
C L — 2.0---2.8 EC mmhos/cm Sat Ext. 8.4-8.0 8.4 pH 1:5 Soil-Water Suspension; 8.0 pH Soil-CaCO3 Suspension

Li C — .65 Hydraulic Conductivity in/hr (Disturbed Samples); 24 Settling Volume

Gr.

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Li	Light
M	Medium
H	Heavy



* Depths listed are in meters. Multiply by 3.28 to obtain feet.

BILLINGS COUNTY
SECTIONS 26,34, - T. 141 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCE SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T. FIECHTL — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — SHEET 2 OF 9 — FEBRUARY, 1979 — 1305-600-273

1:12,000

Sec. 30; T. 141N; R. 97W

1 — 300'W., 100'S. of S1/4 Cor. 0-.15m acceptable surface material. .15-.25m subsurface material. .25-1.7m for use below root zone. 2-4% complex rently sloping bench remnant with strong alkali influence in area. Strong dark orrganic influenced clayey shales at 2.7m. Acid influence 2.5m. .30-.91m, SAR 13.1

7 — 1300'S. of N1/4 Cor. 0-.15m preferred surface material. .15-.25m acceptable for surface. .25-.7m subsurface material. 2-4% complex residual bottom with slick spot influence in area.

5 — 2000'E. of W1/4 Cor. 0-.15m preferred surface material. .15-.61m acceptable for surface. .61-1.4m subsurface use. 2-4% complex colluvial foot slope with numerous slick spots in area. .61m C_{aco}. Sandy shale materials at 1.4m. Class downgrated.

2 — 1100'S., 400'E. of NW Cor. 0-.15m preferred surface material. .15-.61m accentable for surface. .61-1.1m subsurface material. 1.1-3.0m for use below root zone. 2-4% complex foot slope with slick spot influence in area. Salt crystals at .61m.

8 — 1300'W., 100'N. of SE Cor. 0-.15m acceptable for surface. .15-.97m subsurface material. .97m-3.0m for use below root zone. 0-2% complex colluvial bottom with slick spots. Water table at 2.1m. .91-1.1m., Dyp +0.3

6 — 2400'W., 100'S. of E1/4 Cor. 0-.15m acceptable for surface. .15-3.0m subsurface material. 2-4% complex foot slope. Slick spot influence in the area. .30m C_{aco}.

Sec. 32; T. 141N; R. 97W

3 — 500'S., 100'E. of W1/4 Cor. 0-.15m acceptable for surface. .15-.91m subsurface material. .91-3.0m for use below root zone. 2-4% complex colluvial area with slick spot influence. Weathered shales at .15m. .15-.91m., SAR 4.7

1 — 600'W., 100'S. of S1/4 Cor. 0-.76m preferred surface material. .76-1.2m acceptable for surface. 1.2-3.4m subsurface use. 2-4% complex foot slope with slick spot influence in area. .47cm. C_{aco}. Salt crystals 1.2m. Alkali influence in area greater than that reflected by profile. 1.2-1.4m., SAR 6.0

4 — 1400'E., 100'S. of NW Cor. 0-.15m accentable for surface. .15-.76m subsurface material. .76-3.0m for use below root zone. 2-4% complex side slope with slick spot influence. .76m C_{aco}. Weathered shales .76m. Area downgraded due to alkali condition, 60% slick spots.

2 — 400'E., 150'N. of SW Cor. 0-.15m accentable for surface use. .15-.76m subsurface material. .76-3.0m for use below root zone. 2-4% complex side slope with 6-10% side slopes in deviation. .30m C_{aco}. Organic carbon influence from 2.1-2.9m. Semi-consolidated shales at 3.4m. Acid influence 1.9m. .30-.76m., SAR 3.8

5 — 200'E., 100'N. of W1/4 Cor. 0-.91m preferred surface material. .91-1.2m accentable for surface. 1.2-3.0m for subsurface use. 4-6% complex foot slope. Salt crystals .91m.

3 — 150'E., 100'N. of W1/4 Cor. 0-.15m accentable for surface. .15-.76m subsurface material. .76-1.4m for use below root zone. 2-4% complex colluvial foot slope with slick spot influence. Semi-consolidated materials at 2.4m. Profile 7.5Y 5/4 with heavy clayey shales at .91m. 1.4-1.9m, Dyp +2.4

6 — 2300'E. of W1/4 Cor. 0-.15m preferred surface material. .15-.46 subsurface material. .46-3.4m for use below root zone. 2-4% complex side slope with 20% slick spots influencing area. 0cs weathered shale at .25m. Stronger alkali influence with salts in area. .30-.91m., SAR 19.0 2.1-2.7m., Dyp +4.0

4 — 800'E., 300'S. of SW Cor. 0-.15m preferred surface material. .15-.91m accentable for surface use. .91-3.4m subsurface use. 2-4% complex colluvial bottom with sodium influence in area.

* EXPLANATION

LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant media deficiency; Topographic deficiency; aq — Informative symbols

SURFACE LAYER — Quality; Depth

SECOND LAYER — Quality; Depth

Divides soil material and nonsoil material

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- o Sodicity
- s Salinity
- h Cloy (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, floggy or clinkers (soil profile)

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Cobbly, stony, floggy or clinkers (land surface)
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 3.0m DEPTH

3 — SOIL PROFILE NUMBER

C L — 2.8 — 2.8 EC mmhos/cm Sat.Ext.; 8.4-8.0 — 8.4 pH 1:5 Soil-Water Suspension; 8.0 pH Soil-$CaCl_2$ Suspension

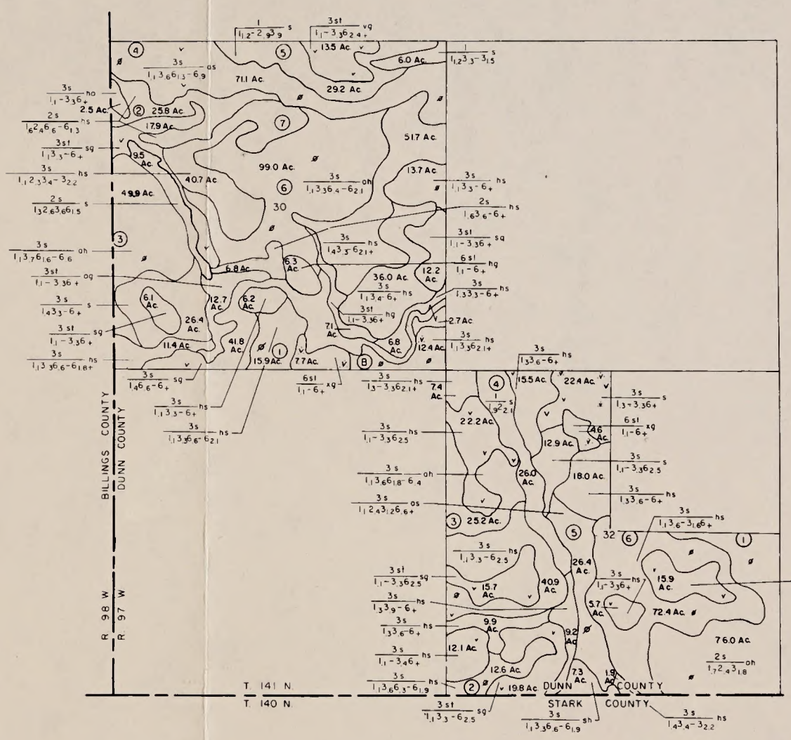
L1 C — 65/24 — .65 Hydraulic Conductivity in/hr (Disturbed Samples); 24 Settling Volume

G_R

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

* Depths listed are in meters. Multiply by 3.28 to obtain feet.



DUNN COUNTY
SECTIONS 30,32 T. 141 N., R. 97 W.

1:12,000

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCE SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T. FIECHTL — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — FEBRUARY, 1979 — SHEET 3 OF 9

1305-600-274

Sec. 2, T. 140N, R. 99W

(1) 1000'N., 300'W. of SE Cor. 0-.30m acceptable surface material. .30-2.5m subsurface material. 2.5-3.0m for use below root zone. 2-4% complex area with 30% slick spots. Sandy shales soft to semi-consolidated. Salt crystals 1.5m. .30-.76m., SAR 6.8

(7) 1100'N., 30.5'E. of SW Cor. 0-.30m preferred surface material. .30-.61m acceptable for surface. .61-3.0m for subsurface use. 2-4% complex foot slope with 6-10% slopes on crests. .61m semi-consolidated clayey shales with salt crystals. Sodium influence in area.

(4) 1100'E., 1008'N of W1/4 Cor. 0-.30m preferred surface material. .30-.51m acceptable for surface. .61-2.1m subsurface material. 2.1-3.0m for use below root zone. 4-8% complex slope-stronger slopes up to 16% in the area. Below 1.3m semi-consolidated sandy shales, 1.3-1.9m., SAR 9.0 Gyp +1.6

Sec. 12, T. 140N, R. 99W

(1) 1400'E., 1000'N of SW Cor. 0-.30m preferred surface material. .30-3.0m acceptable for surface. 4-6% complex general slope with crests varying from 8-12%. Textures approaching FSL at 1.8m. Salt crystals at 1.1m. Profile taken in gentle swale.

Sec. 14, T. 140N., R. 99W

(1) 700'N., 200'E. of W1/4 Cor. 0-.15m acceptable for surface use. .15-1.2m subsurface use. 1.2-3.0m use below root zone. 0-2% complex colluvial area of degraded and solodized solonetz soils. Slick spots 40% of area. Salt crystals at .61m. 1.2-1.8m., SAR 27.7m Gyp -1.2

(6) 500'N., 300'W. of E1/4 Cor. 0-.30m acceptable for surface. .30-2.7m for use below root zone. 2-4% complex foot slope with slick spots in area. .10-.76m weathered shales. Water table at 2.7m.

(2) 1400'N., 200'W of S1/4 Cor. 0-.15m acceptable for surface. .15-.45m subsurface material. .45-3.0m for use below root zone. 2-4% complex colluvial foot slope with up to 50% slick spots. Free water at 1.2m. Stratified sandy shales with carbonaceous influence at 2.2m. .30-.76m., SAR 11.3

(8) 300'W., 200'N. of S1/4 Cor. 0-.30m acceptable for surface. .30-3.0m subsurface material. 4-8% general side slopes with slopes to 12% on shallower crests. Salt crystal from .76m becoming more concentrated at 1.9m. Profile less than 30.5m from crest. .45-.76m., SAR 5.7

(5) 800'W., 600'S. of N1/4 Cor. 0-.15m acceptable for surface. .15-1.2m subsurface material. 1.1-3.0m for use below root zone. 2-4% complex gently sloping side slopes with slick spot in area. Salt crystals at .45m. 1.6-2.2m., SAR 17.0 Gyp. +2.0

(2) 1300'W., 200'N. of SE Cor. 0-.15m acceptable for surface. .15-.45m subsurface material. .45-3.0m for use below root zone. 2-4% complex colluvial foot slope with slick spots. Area 70% degraded solonetz soils-profile representative. .30-.76m., SAR 19.0

(2) 600'S., 200'E. of W1/4 Cor. 0-.30m preferred material. .30-.45m acceptable for surface. .45-.91m for subsurface use. .91-2.7m use below root zone. 2-6% complex foot slope below gentle high. Slick spots prevailing over area with scattered rocks on surface. Depth to shale on crest averaging .61m.

(7) 1000'S., 500'E. of N1/4 Cor. 0-.15m preferred surface material. .15-.45m acceptable for surface. .45-3.0m subsurface use. 2-4% complex subsoil with slick spots in area. .91m salt crystals. Slick spot influence in area. .91-1.3m., SAR 10.4 2.4-3.0m., SAR 11.1

(3) 2300'W., 300'N. of S1/4 Cor. 0-.15m preferred surface material. .45-1.2m acceptable for surface. 1.2-3.0m subsurface material. 2-6% complex side slope in upper part of swale. Salt accumulation at .76m. Shales soft sandy material.

(9) 1600'S., 100'E. of N1/4 Cor. 0-.15m acceptable for surface. .15-.45m for subsurface use. .45-3.0m for use below root zone. 4-6% complex side slope below shallow crests. Salt crystals at .76m. Sodium influence in lower levels.

(6) 1000'S., 200'E of N1/4 Cor. 0-.61m acceptable for surface. .61-1.2m for subsurface use. 1.2-3.0m for use below root zone. 2-4% complex colluvial foot sloce adjacent to swale. Area higher has shallow A/C profile. Semi-consolidated material at 2.4m. 1.2-1.8m., SAR 13.0 Gyp. +1.6

(3) 1400'N., 300'E. of S1/4 Cor. 0-.15m acceptable for surface. .15-.61m subsurface material. .61-3.0m for use below root zone. 0-2% complex colluvial bottom with slick spots. Overall the materials are better than indicated in delineated area. .45-.91m., SAR 17.6 Alluvial bottom with deeper surface materials.

(3) 1500'N. of S1/4 Cor. 0-.45m preferred surface material. .45-.91m for subsurface use. .91-3.0m for use below root zone. 0-2% complex colluvial solodized solonetz soils with 50-60% of area being slick spots. Baked shale fragments from .45-.91m. Salt crystals at .45m. .45-.91m., SAR 9.4

(8) 1100'W., 100'S. of N1/4 Cor. 0-.15m acceptable for surface. .15-3.0m subsurface material. 2-4% complex side slope with slopes to 10% near crests. Soft sandy shales at 1.8m. Strong alkali influence in area.

(4) 500'S., 100'W. of E1/4 Cor. 0-.30m preferred surface material. .30-.76m acceptable for surface. .76-1.2m subsurface use. Weathered shales from .76m to 1.1m. Solonetz influence in area. Salt crystals at 1.1m. Surface materials averaged for area.

Sec. 10, T. 140N., R99W

(1) 700'N., 100'W. of SE Cor. 0-.30m acceptable for surface use. .30-.91m subsurface material. .91-3.0m for use below root zone. 2-4% complex side slope with slick spots in area. Clayey shales semi-consolidated at 2.1m. Salt crystals at 1.1m. .30-.91m., SAR 9.2

(7) 700'N., 100'E. of W1/4 Cor. 0-.15m acceptable for surface. .15-3.0m subsurface material. 2-4% complex colluvial bottom with 40% slick spots. .45-.76m., SAR 9.3

(4) 1900'N. of S1/4 Cor. 0-.15m acceptable for surface. .15-.61m subsurface material. .61-3.0m for use below root zone. 0-2% complex colluvial bottom with slick spots oredominately in area. Maximum salt accumulation 1.5-1.8m. 1.2-1.8m, SAR 11.4

(4) 1000'N., 200'W. of SE Cor. 0-.45m preferred surface material. .45-3.0m subsurface use. 0-2% complex colluvial area located in gentle swale. 132.0m W. orofile with shales at .91m.

(9) 1000'E. of SW Cor. Refer to Point Site #9 Land Characterization Descrintion.

(5) 350'N., 350'W. of E1/4 Cor. 0-.45m acceptable for surface. .45-.76m subsurface use. .76-3.0m for use below root zone. 2-4% gentle side slope with 60% slick spot influence. Salt crystals at .45m. .45-.76m., SAR 13.0

(2) 2200'W., 400'S. of E1/4 Cor. 0-.15m preferred surface material. .15-.76m for subsurface use. .76-3.0m for use below root zone. 0-2% complex colluvial bench with slick spots in area. Free water at 2.1m. .67-1.2m., SAR 13.3

(8) 600'S., 100'E. of W1/4 Cor. 0-.76m preferred surface material. .76-.91m acceptable for surface. .91-3.0m subsurface material. 4-8% complex side slope. Profile located midway between shallow crest and swale. Average effective depth on high areas .45m.

(5) 1100'W., 1200'N. of E1/4 Cor. 0-.15m acceptable for surface. .15-3.0m subsurface material. 0-2% complex colluvial foot slope with slick spot influence. Water table at 2.5m. Salt crystals at .76m.

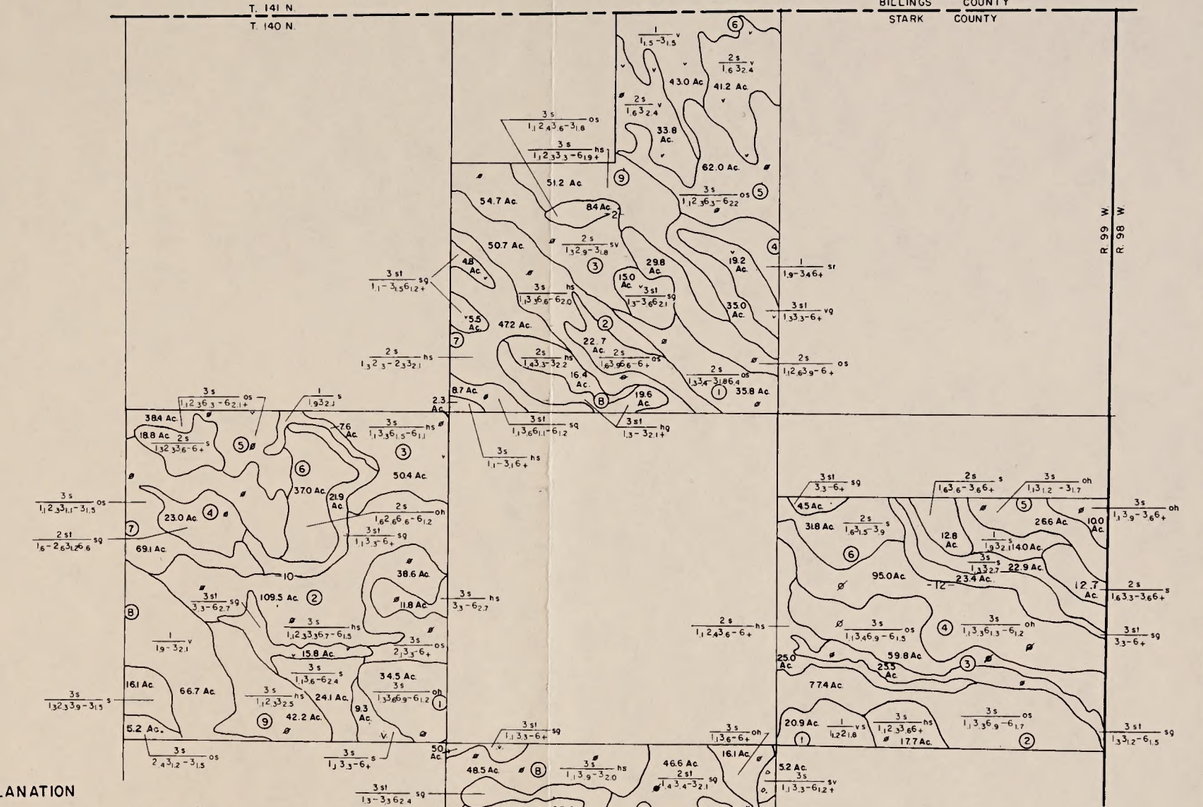
(5) 1600'W. of E1/4 Cor. 0-.30m preferred surface material. .30-1.5m acceptable for surface. 1.5-2.1m for subsurface use. 0-2% complex colluvial soil with 20% slick spots in area. Water table at 1.8m. Seep area. Salt crystals at .30m.

(6) 800'W., 200'S. of NE Cor. 0-.45m preferred surface material. .45-1.2 acceptable for surface. 1.2-3.0m subsurface material. 2-4% complex slopes with short crests approaching 6% slopes. Crusty sandy material at 1.5m.

(3) 800'W., 600'S. of NE Cor. 0-.15m preferred surface material. .15-.45m subsurface use. .45-3.0m for use below root zone. 0-2% complex colluvial bottom with 30% slick spots in area. Salt accumulation at 1.3m. .45-.76m., SAR 13.9 1.3-1.9m., SAR 11.7

(9) 400'W., 300'N. of S1/4 Cor. 0-.45m acceptable for surface. .45-3.0m subsurface material. 2-4% complex colluvial foot slope with slick spots. Salt crystals at .45m. 1.5-1.9m., SAR 6.8

(6) 1200'E., 400'N. of W1/4 Cor. 0-.61m preferred surface material. .61-3.0m subsurface material. 4-8% complex side slope with 12% slopes in area. Salt accumulations heavy 1.8m. Soft red shales from 2.2m. Averare crest depth at .15m.



* EXPLANATION

LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant medio deficiency; Topographic deficiency; og — Informative symbols

SURFACE LAYER — Quality, Depth

SECOND LAYER — Quality, Depth

Divides soil material and subsoil material

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- o Sodicity
- s Solinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, floggy or clinkers (soil profile)

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Cobbly, stony, floggy or clinkers (land surface)
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 3.10M DEPTH

3 SOIL PROFILE NUMBER

C L — 2.8---2.8 EC mmhos/cm Sat.Ext.; 8.4-8.0 8.4 pH 1:5 Soil-Water Suspension; 8.0 pH Soil-CaCl2 Suspension

Li C — .65 Hydraulic Conductivity in/hr (Disturbed Samples)

.65/24 — 24 Settling Volume

Gr

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

* Depths listed are in meters. Multiply by 3.28 to obtain feet.

1:12,000

STARK COUNTY
SECTIONS 2, 10, 12, 14 - T 140 N., R 99 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCE SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COAL FIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T. FIECHTL	SUBMITTED
DRAWN L.E. ALLSOP	RECOMMENDED
CHECKED	APPROVED

BILLINGS, MONTANA — SHEET 4 OF 9 — FEBRUARY, 1979

1305 - 600 - 275

Sec. 4, T. 140N., R. 98W
600'N., 200'E. of NW Cor. 0-.15m acceptable surface material. .15-1.2m subsurface material. 1.2-3.0m for use below root zone. 2-4% complex colluvial foot slope with 6-8% slopes on crests. Salt crystals at 1.6m.

Sec. 6, T. 140N., R. 98W
1400'E., 1000'N., of SE Cor. 0-.15m preferred surface material. .15-1.2m acceptable for surface. 1.2-3.0m subsurface material. 2-6% complex sandy crest with stronger slopes in area.

700'W., 500'S. of NE Cor. 0-.91m acceptable for surface. .91-1.5m subsurface use. 1.5-3.0m for use below root zone. 2-4% complex gently rolling shallow to moderately deep to shale area. Slick spot influence area. 1.1-1.5m., SAR 11.4

1400'S., 600'E. of NW Cor. 0-.15m acceptable surface material. .15-3.0m subsurface material. 0-2% complex colluvial bottom. Salt accumulations at 1.3-1.5m. .76-1.2m., SAR 3.8

900'W., 500'N. of SE Cor. 0-.30m acceptable for surface. .30-2.1m for subsurface use. 4-6% complex general side slope. Salt crystals at .30m. Coal like material at 2.1m.which is not consistant with total deliniated area. Isolated cores or cockets of baked shales are in area. .91-1.5m., SAR 9.8

1100'W., 900'N. of W1/4 Cor. 0-.15m acceptable for surface. .15-1.2m for subsurface use. 1.2-3.0m for use below root zone. 2-4% side slopes with 6% slopes in area. Salt crystals at .45m. Weathered shales .15m.

500'S. of N1/4 Cor. 0-.30m acceptable for surface. .30-2.4m subsurface material. 2-4% complex side slope. Weathered shale from 1.1-1.8m. .91-1.3m., SAR 1.3

800'W., 300'N. of S1/4 Cor. 0-.61m preferred surface material. .61-1.0m acceptable for surface. 2-4% complex side slope. Sandy shales semi-consolidated.

800'W., 400'S. of N1/4 Cor. 0-.30m acceptable for surface. .30-.61m for subsurface use. .61-3.0m for use below root zone. 2-4% complex side slopes with slick spots in area. Weathered shales at .91m. Bedrock material was first encountered at .91m. .61-.91m., SAR 11.4

500'W., 200'S. of NE Cor. 0-.15m acceptable surface material. .15-.76m subsurface material. 2-4% complex slick spot influence area. Salt crystals at .76m. Salt crystals noticeable at .76m.

1700'W., 700'N. of E1/4 Cor. 0-.15m preferred surface material. .15-.45m acceptable for surface. .45-1.1m for subsurface use. 1.1-2.4m for use below root zone. 2-4% general slope with slopes to 6% on crests. Area is in a cumulative position with slick spot influence in area. Salt crystals .38m.

200'W., 800'E. of W1/4 Cor. 0-3.0 material to be placed below root zone. Surface/subsurface to be borrowed. 2-4% complex foot slope with slick spots. Sodium dominated delination. 0-.30m., SAR 22.5

1000'W., 200'S. of NE Cor. 0-.15m acceptable for surface. .15-3.0m subsurface material. 0-2% colluvial bottom with slick spot influence area. Water table at 2.1m. Salt crystals noticeable at .76m.

1000'W., 200'S. of SW Cor. 0-.15m preferred surface material. .15-1.2m acceptable for surface. 1.2-3.0m subsurface material. 4-8% complex side slope. .45-.91m FSL-SCL weathered shales. Stratified LFS/FS at 1.3m.

1200'S., 1200'S. of NW Cor. 0-.15m acceptable for surface. .15-1.3m subsurface material. 0-2% complex colluvial foot slope with slick spot influence in area. .76-1.1m gravelly CL. 1.1-1.3m very gravely sandy loam. Gravels are baked shales. .45-.76m., SAR 10.6

300'E., 300'S. of N1/4 Cor. 0-.76m preferred surface material. .76-1.2m acceptable for surface. 1.2-3.0m subsurface material. 4-8% complex moderately sloping crest. Loose fine sandy loam surface with sandy shale outcropping on steeper crests. 1.2-1.8m., SAR 1.3

1600'W. of S1/4 Cor. 0-.15m acceptable for surface .15-1.9 subsurface ste. 1.3m+ use below root zone. Complex colluvial area with slick spots. Salt crystals at .91m. Heavy clayey material at 1.6m.

600'W., 200'S. of N1/4 Cor. 0-.30m acceptable surface material. .30-1.1m for subsurface use. 1.1-3.0m for use below root zone. 2-4% complex foot slope below baked shale. Salt crystals at .61m. On to 10% slick spots in area.

500'N., 200'E. of E1/4 Cor. 0-.15m acceptable for surface. .15-1.2m for subsurface use. 1.2-3.0m for use below root zone. 0-2% complex slick spot area. Salt crystals at .61m.

1500'E., 500'S. of W1/4 Cor. 0-.15m acceptable for surface. .15-1.2m subsurface material. 1.2-3.0m for use below root zone. 0-2% complex bottom with 20% slick spots in area. Salt crystals .45m. Shales lighter with depth. 1.2-1.8m., SAR 11.9

Sec. 8, T. 140N., R. 98W
1300'E., 200'N. of SW Cor. 0-.15m preferred surface material. .15-.30m acceptable for surface. .30-3.0m for subsurface use. 2-4% side slope with slick spots in area. Semi-consolidated sandy shales at 1.2m. Salt crystals at .38m. .30-.61m., SAR 10.4

700'E., 200'S. of NW Cor. Refer to Point Site #7 Land Characterization Description.

500'S., 400'W. of SE Cor. 0-.15m acceptable for surface. .15-3.0m for subsurface use. 2-4% complex colluvial foot slope. Salt crystals .45m.

1100'W., 200'N. of SE Cor. 0-.61m preferred surface material. .61-1.2m acceptable for surface. 1.2-1.7m subsurface material. 4-8% complex side slopes with some stronger slopes in area. Semi-consolidated sandy shales at 1.5m. 91-12m., SAR 4.7

1300'W., 300'N. of SE Cor. 0-.15m acceptable for surface. .15-.61m subsurface material. .61-3.0m for use below root zone. 2-4% complex foot slope with slick spots 20% in area. Sandy shales approaching FS at 3.0m. Salt crystals at .76m. .30-.76m., SAR 13.9

300'W., 100'S. of W1/4 Cor. 0-.61m preferred surface material. .61-.91m acceptable for surface. .91-1.0m for subsurface use. 2-4% complex side slope with profile midway between crest and swale. Stratified FS/FSL from 1.4-2.1m. Some salt accumulations from 2.1-2.4m.

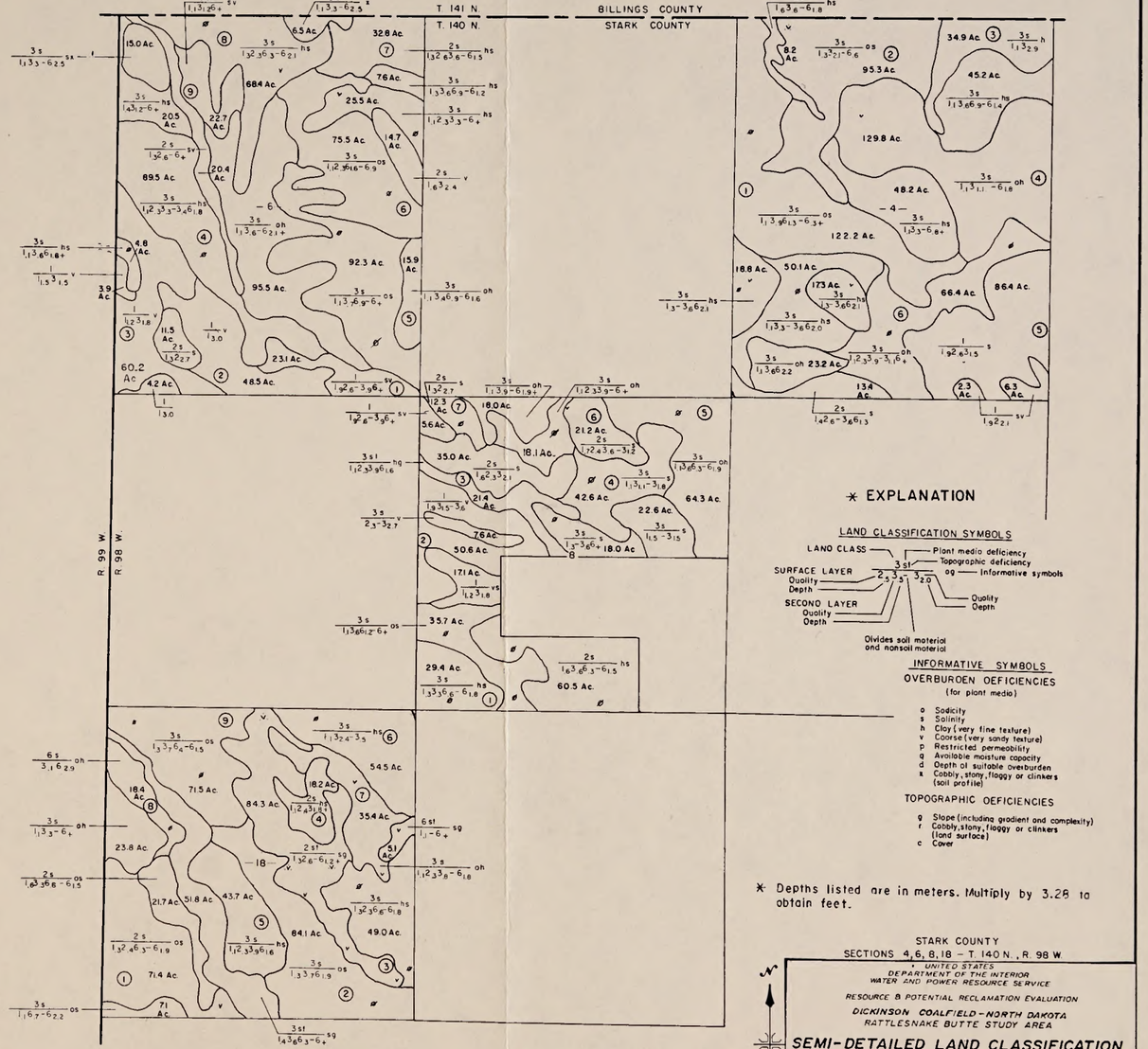
600'W., 100'S. of SW Cor. 0-.30m preferred surface material. .30-.76m acceptable for surface. .76-2.1m for use below root zone. 2-4% complex side slope with slick spots in area. Coal material at 2.1m. Quality of surface material averaged for area. .76-1.1m., SAR 12.0 Gyp. +1.7

Sec. 18, T. 140N., R. 98W
600'W., 100'S. of SW Cor. 0-.30m preferred surface material. .30-.76m acceptable for surface. .76-2.1m for use below root zone. 2-4% complex side slope with slick spots in area. Coal material at 2.1m. Quality of surface material averaged for area. .76-1.1m., SAR 12.0 Gyp. +1.7

SOIL PROFILE NOTES
PROFILE REPRESENTS SOIMDEPTH
3 SOIL PROFILE NUMBER
CL 2.8---2.8 EC mmhos/cm Sat.Ext.
8.4-8.0 8.4 pH 1:5 Soil-Water Suspension
8.0 pH Sat.-CaCO3 Suspension
65 / 24 Li C ------ .65 Hydraulic Conductivity in/hr (Disturbed Samples)
Gr ----- 24 Settling Volume

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Li	Light
M	Medium
H	Heavy



* EXPLANATION

LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant media deficiency; Topographic deficiency; og — Informative symbols

SURFACE LAYER — Quality; Depth

SECOND LAYER — Quality; Depth

Divides soil material and nonsoil material

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- a Available moisture capacity
- d Depth of suitable overburden
- k Cobbly, stony, floggy or clinkers (soil profile)

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Cobbly, stony, floggy or clinkers (land surface)
- c Cover

* Depths listed are in meters. Multiply by 3.28 to obtain feet.

STARK COUNTY
SECTIONS 4,6,8,18 - T 140 N., R 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCE SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SEMI-DETAILED LAND CLASSIFICATION

1:12,000

CLASSIFIED T. FIECHTL — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — FEBRUARY, 1979 — SHEET 8 OF 9 — 1305-600-276

Sec. 2, T. 140N, R. 98W

(1) 900'W., 200'N. of S1/4 Cor. 0-.30m preferred surface material. .30-1.0m acceptable for surface. 1.6-3.0m for subsurface use. 4-6% complex side slopes below shallow to sandy shale crests. Crests average .15-.30m to sandy shales. Salt crystals at 1.6m.

(7) 1500'N., 400'E. of W1/4 Cor. 0-.15m acceptable for surface. .15-.91m subsurface material. .91-3.0m for use below surface. 2-4% complex colluvial foot slope. Salt crystals at .67m.

(3) 1700'W., 1000'N. of E1/4 Cor. 0-.15m acceptable surface material. .15-3.0m subsurface material. 2-4% complex side slopes. Carbonaceous influence at 1.3m. Salt crystals at .38m, .30-.76m., SAR 7.9

Sec. 14, T. 140N., R. 98W

(1) 1250'E., 500'S. of W1/4 Cor. 0-.30m acceptable for surface, .30-.91m subsurface material. .91-3.0m for use below root zone. 2-4% complex foot slope with slick spots in area. Free water at 2.1m.

(2) 1100'N., 300'W. of SE Cor. 0-.91m preferred surface material. .91-2.1m acceptable for surface. 2.1-3.0m subsurface use. 2-4% side slope. 2.1-2.7m, SAR 8.6

(8) 750'S., 200'E. of W1/4 Cor. 0-.15m acceptable for surface. .15-1.7m subsurface material. 1.7-3.0m for use below root zone. 0-2% complex colluvial bottom with 50% slick spots in area. Salt crystals at .15m, .05-.76m., SAR 10.2

(4) 1250'S., 150'W. of NE Cor. 0-.30m preferred surface material. .30-1.7m acceptable for surface. 1.2-3.0m subsurface material. 0-2% complex foot slope with slick spot influence in area.

(2) 600'W. 600'N. of S1/4 Cor. 0-.30m acceptable surface material. .30-1.0m subsurface material. 2-4% complex side slope with 6-8% slopes in area. .38-.70m weathered shale material.

(3) 2000'W., 700'S. of E1/4 Cor. 0-.30m acceptable for surface. .30-3.0m subsurface material. 2-4% complex colluvial foot slope with slick spot influence in area. Water table at shale line. .61-1.3m., SAR 1.0

(9) 750'S., 200'E. of W1/4 Cor. 0-.15 accentable surface material. .15-1.2 subsurface material. 1.2-3.0m for use below root zone. Profile taken from slick spot in association with profile #8. 1:1 composit samples from profiles 8 and 9 indicate a surface increase in salts and hydraulic conductivity.

(5) 500'S., 500'W. of N1/4 Cor. 0-.70m preferred surface material. .30-3.0 subsurface use. 2-4% complex swale. Water table at 2.7m. Salt crystals at 1.1m.

(3) 700'N., 400'E. of W1/4 Cor. 0-.30m preferred surface material. .30-2.7m for subsurface use. 2.7-3.0m for use below root zone. 2-4% complex colluvial foot slope with slick spots in area. 41mm accumulations at .30m. Free water at 2.7m. 1.5-2.1m., SAR 12.0

(4) 2500'E., 200'N. of W1/4 Cor. 0-.30m preferred surface materials. .30-1.2m acceptable for surface. 1.2-3.0m subsurface use. 2-4% complex side slope with slick spot influence in area.

(10) 1400'N., 800'W. of S1/4 Cor. 0-.15m acceptable for surface. .15-1.1 subsurface material. 1.1-3.0m for use below root zone. 0-2% complex colluvial area with slick spots. Bedrock material may be localized. Salt crystals at .67m. .30-.76m, SAR 9.1

(6) 750'S., 100'E. of NW Cor. 0-.91m preferred surface material. .91-3.0m acceptable for surface. 2-4% complex swale with crests from 1-2%.

(4) 1000'S., 1000'W. of N1/4 Cor. 0-.15m acceptable surface material. .15-3.0m for subsurface use. 2-4% complex side slope with slick spots in area. .91m weathered shales. Some free water at 2.7m.

Sec. 15, T. 140N., R. 98W

(5) 1300'N., 300'W. of E1/4 Cor. 0-.30m acceptable for surface. .30-1.2m subsurface material. 1.2-3.0m for use below root zone. 2-4% complex side slope. Average depth to sandy shales on crest at .30m. Weathered shales from .61-1.2m. Salt crystals at .25m. 1.2-1.8m., SAR 15.6

(1) 350'N., 100'E. of W1/4 Cor. 0-.15m acceptable for surface. .15-3.0m subsurface material. 0-2% complex swale with slick spots in area. Oxidized sandy shales at 1.2m. Salt crystals at .76m.

(7) 1400'E., 400'S. of NW Cor. Refer to Point Site #7 Land Characterization Description.

(5) 500'S., 300'W. of N1/4 Cor. 0-.30m preferred surface material. .30-3.0m subsurface. 4-6% side slope. Stratified sandy shales at 1.5m. Profile average depth to shale- zone depth in swales with crests ranging from 6-12". Surface .30m slightly acid.

(6) 200'E., 200'S. of N1/4 Cor. 0-.15m acceptable for surface. .15-.45m for subsurface use. .45-3.0m use below root zone. 2-4% complex side slope with slick spot influence in area. Weathered shales from .45-1.1m. Salt accumulation at 1.1m, 0-.45m., SAR 7.7

(2) 1700'E., 500'N. of W1/4 Cor. 0-.15m acceptable for surface. .15-2.1m subsurface material. 2.1-3.0m for use below root zone. 2-4% complex side slope with slick spots in area. Carbonaceous influence from 1.1 to 1.5m. Salt crystals at .45m. 0-.45m., SAR 9.2

(8) 200'E., 100'S. of N1/4 Cor. Refer to Point Site #8 Land Characterization Description.

EXPLANATION *

LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 s 1 — Plant media deficiency; Topographic deficiency; og — Informative symbols

SURFACE LAYER — Quality, Depth — 2 s 3 s 3 s 2 0

SECOND LAYER — Quality, Depth

Divides soil material and nonsoil material

Quality, Depth

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, floggy or clinkers (soil profile)

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Cobbly, stony, floggy or clinkers (land surface)
- e Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 300M DEPTH

(3) SOIL PROFILE NUMBER

C L — 2.8 --- 2.8 EC mmhos/cm Sat. Ext.

L1 C — 8.4-8.0 8.4 pH 1:5 Salt-Water Suspension; 8.0 pH Sat-CaCl2 Suspension

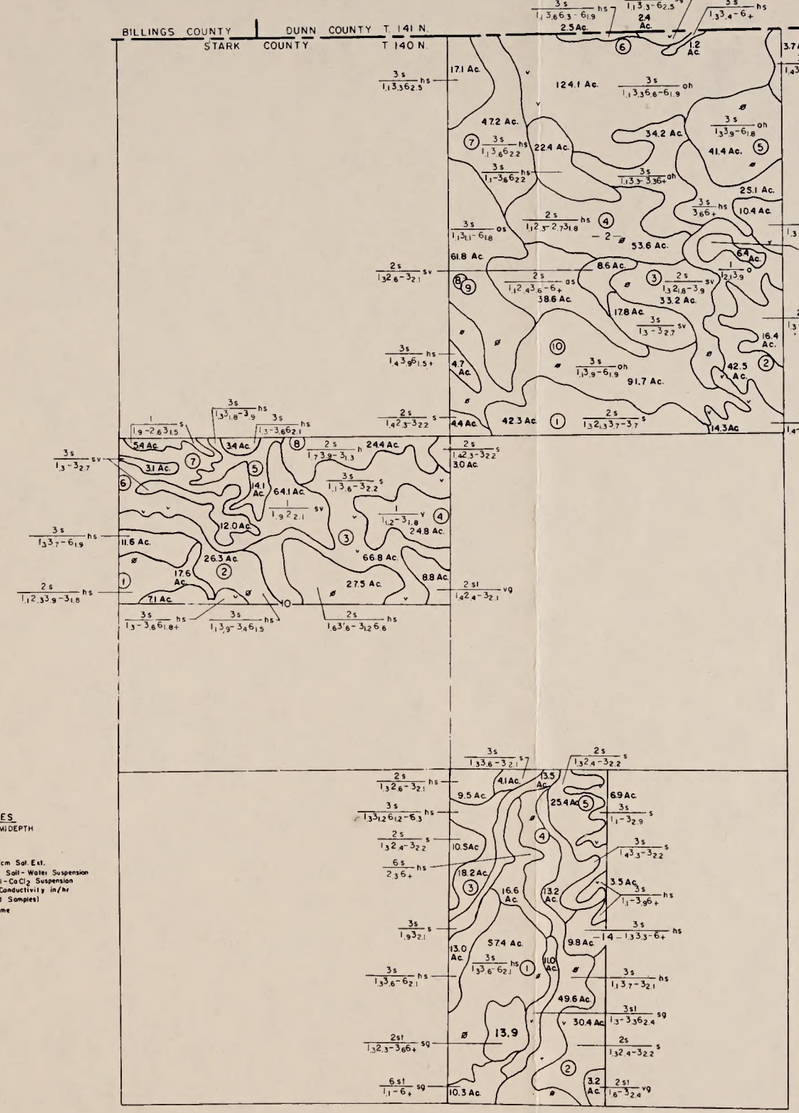
.65 — ----- .65 Hydraulic Conductivity in/hr. (Disturbed Samples)

Gr — ---- 24 Settling Volume

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Li	Light
M	Medium
H	Heavy

* Depths listed are in meters. Multiply by 3.28 to obtain feet.



1:12,000

STARK COUNTY
SECTIONS 2,10,14 - T. 140 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCE SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T. FIECHTL — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — FEBRUARY, 1979 — SHEET 6 OF 9

1305 - 600 - 277

(1) Sec. 22, T. 140N, R. 99W
900'W., 150'N. of SE Cor. 0-.30m preferred surface material. .30-.91m acceptable for surface. .91-3.0m subsurface material. 2-4% complex swale-side slope with slopes in area from 6-8%. Fine sande have lime accumulations. Profile 91.5m W on side slope with 0-.45m FSL, .45-.61m LFS., .61m+FS.

(7) 1100'W., 100'E. of W1/4 Cor. 0-.15m preferred surface material. .15-.45m acceptable for surface. .45-1.0m for subsurface use. 2-4% complex side slope. Salt crystals at .38m. L=0-2.2m., SAR 0.2

(3) 1400'S., 400'W. of N1/4 Cor. 0-.30m acceptable for surface. .30-1.2m for subsurface use. 1.2-2.1m for use below root zone. 2-4% complex side slope. 2.1m coal material. Crests with .30-.45m over sandy shales. Surface .30m is slightly acid. Salt crystals at .30m.

(2) 1000'S., 300'W. of S1/4 Cor. 0-.15m acceptable surface material. .15-1.1m subsurface material. 1.1-1.9m for use below root zone. 2-4% complex side slope with 6-8% slopes in area adjacent to draw. Slick spots throughout area. 1.1-1.5m stratified CL/C. Salt crystals at .15m.

(1) Sec. 14, T. 140N, R 99W.
500'S., 50'E. of W1/4 Cor. 0-.30m acceptable surface material. .30-2.1m subsurface use. 4-6% complex side slope with slick spots in area. Weathered shales .45-.91m. Semi-consolidated material at 1.4m. Slightly acid at 1.0-2.1m, 1.3-1.6m., SAR 22.4 Gyp +.5

(5) 1000'W., 400'S. of NE Cor. 0-.15m acceptable for surface material. .15-1.7m for use below root zone. 2-4% complex side slope. Weathered shales at .76-1.1m.

(2) 1700'N., 500'E. of S1/4 Cor. 0-.30m preferred surface material. .30-.91m acceptable for surface use. .91-3.0m subsurface material. 4-8% complex side slope. Oxidized sandy shale material at 2.1m.

(8) 900'E., 300'S. of NW Cor. 0-.30m preferred material. .30-1.2m acceptable for surface. 1.2-2.2m subsurface material. 2-4% foot slope with sandy side slopes from 6-8%. Coal like shales at 2.1m. Profile located adjacent to swale. Crests have .45m reclamation material. .45-1.1m., SAR 2.2

(6) 600'S., 400'W. of NE Cor. 0-.15m acceptable for surface. .15-1.0m for use below root zone. 2-4% complex side slopes with 40% slick spot influence in area. .30m clayey weathered shales/salt crystals, .30-.91m., SAR 7.8

(3) 600'S., 500'W. of S1/4 Cor. 0-.15m preferred surface material. .15-.45m acceptable for surface use. .45-2.0m subsurface material. 2-4% colluvial broad swale. Weathered shale material .91-1.5m. 1.8-2.1m., SAR 3.7 2.4-3.0m., SAR 3.8

(2) 1100'S., 900'W. of W1/4 Cor. 0-.76m subsurface material-clayey shales . 4-8% complex side slope with baked shales outcropping in area. Weathered shales to .76m. Baked shales at .76m. Salts outcropping on lower slopes. .45-.76m., SAR 3.9

(3) 700'W., 100'N. of S1/4 Cor. 0-.15m acceptable surface material. .15-3.0m subsurface use. 2-4% complex side slope with slick spots in area. Salt crystals in area. .30-.91m., SAR 8.6

(1) Sec. 24, T. 140N., R. 99W
1000'N., 800'W. of S1/4 Cor. 0-.30m acceptable for surface. .30-3.0m subsurface material. 2-4% complex side slope. Water table at 2.1m. .30-.76m., SAR 23.9, Gyp -0.6

(7) 800'W., 500'N. of S1/4 Cor. 0-.30m acceptable for surface. .30-1.0m for use below root zone. 0-2% complex colluvial area with slick spots. Carbonaceous shale influence 1.1 to 1.6m. Salt crystals .30-3.0m.

(4) 1500'N., 600'W. of S1/4 Cor. 0-.30m acceptable surface material. .30-3.0m subsurface. use. 2-4% complex foot slope with slick spots in area. Dense material .30-.76m. Profile 152.5m S. with .61m of CL over clay material. 1.2-1.9m., SAR 7.6

(3) 1300'S., 150'E. of NW Cor. 0-.15m preferred surface material. .15-.61m acceptable for surface use. .61-1.2m for subsurface use. 2-4% complex slick spot areas shallow to moderately deep over shales. .91m oxidized sandy shale. 1.2m coal shales.

(4) 1200'E., 300'N of W1/4 Cor. 0-.45m oreferred surface material. .45-.61m acceptable for surface use. .61-3.0m subsurface material. 4-6% complex side slopes. Stronger slopes on sandy crests to 8%. Clayey oxidized shales in area. 2.1-3.0m., SAR 3.8

(2) 350'E. of W1/4 Cor. 0-.45 acceptable for surface. .45-1.1m for subsurface use. 1.1-3.0m use below root zone. 0-2% complex colluvial soil with slick spots. Stratified ferric/ferrous oxidized shales from 1.1m. .45-1.1m., SAR 12.5

(8) 300'N., 100'W. of S1/4 Cor. 0-.30m acceptable for surface. .30-3.0m for use below root zone. Gently to strongly sloping alluvial bottom. Water table at 2.1m. Surface .61m is slightly acid. Salt crystals from .61-3.0m, .61-1.1m., SAR 22.6 Gyp -.2

(5) 1300'S., 800'E. of N1/4 Cor. 0-.61m preferred surface material. .61-2.7m acceptable for surface use. 6-10% side slope. Profile located midway on eide slope. Heavy textured shales at 2.1m.

(4) 1200'W., 1100'N. of SE Cor. 0-.30m preferred surface material. .30-.61m acceptable for surface use. .61-1.2m subsurface material. 2-4% complex side slope on gentle high. Slopes stronner adjacent to draws. Oxidized sandy shales .30m. Coal shales at 1.3m.

(5) 1200'W., 300'S of E1/4 Cor. 0-.15m preferred surface material. .15-.45m acceptable for surface use. 0-2% complex colluvial bottom with slick spots in area. Water table at 1.6m. Salt crystals increasing with depth strongly concentrated 1.5m. Acid influence at 1.5m.

(3) 250'S., 150'E. of NW Cor. 0-.15m acceptable for surface. .15-.76m subsurface material. .76-3.0m for use below root zone. 2-4% complex side slope on gentle crest. Downgraded, 20% slick spots in area. Salt crystals .30m.

(9) 1300'N., 800'E. of S1/4 Cor. 0-.30m acceptable for surface. .30-1.8 subsurface material. 1.8-3.0m for use below root aone. 2-4% complex colluvial slope. 40% slick spot area. .30-.61m, SAR 8.9

(6) 900'N., 250'W. of E1/4 Cor. 0-.61m preferred surface material. .61-2.1m subsurface material. 6-8% side slope. Average depth for materials in area. Crest are shallow for surface material.

(6) 900'W., 50'S. of NE Cor. 0-.45m subsurface material. .45-3.0m for use below root zone. 0-2% complex colluvial bottom with 60% slick spots in area. Water table at 2.7m. Salt crystals from .46m. 0-.45m., SAR 5.1

(4) 200'S. of N1/4 Cor. 0-.30m oreferred surface material. .30-.91m acceptable for surface. .91-3.0m for subsurface use. 0-2% colluvial bottom with some slick spot influence. Thin calcareous accumulation at 2.1m. Surface 1.5m. slightly acid. Acceptable for reclamation material.

(1) Sec. 26, T. 140N, R. 99W.
400'N., 100'E. of SW Cor. 0-.61m oreferred surface material. .61-3.0m acceptable for surface material. 2-4% complex side slope with 6-8% in area near crests. Shallow profiles on crests with 10" SL over LS.

(7) 400'E., 150'S. of E1/4 Cor. Refer to Point Site #7 Land Characterization Description.

SOIL PROFILE NOTES

(3) SOIL PROFILE NUMBER

CL
2.8---- 2.8 EC mmhos/cm Sat.Ext.
84-80 8.4 pH 1:5 Soil-Water Suspension
8.0 pH Soil-$CaCl_2$ Suspension
---- .65 Hydraulic Conductivity in/hr (Disturbed Samples)
65/24 LI C
---- 24 Settling Volume
Gr

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
LI	Light
M	Medium
H	Heavy

EXPLANATION *

LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant media deficiency; Topographic deficiency; qg — Informative symbols
SURFACE LAYER — Quality / Depth
SECOND LAYER — Quality / Depth
3st 2-5 5-3 3-20
Divides soil material and nonsoil material

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

o	Sodicity
s	Salinity
h	Clay(very fine texture)
v	Coarse(very sandy texture)
p	Restricted permeability
q	Available moisture capacity
d	Depth of suitable overburden
x	Cobbly, stony, flaggy or clinkers (soil profile)

TOPOGRAPHIC DEFICIENCIES

g	Slope (including gradient and complexity)
r	Cobbly, stony, flaggy or clinkers (land surface)
c	Cover

* Depths listed ore in meters. Multiply by 3.28 to obtain feet.



STARK COUNTY
SECTIONS 22, 24, 26, 34 - T 140 N, R 99 W

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCE SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION
DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T. FIECHTL — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY, 1979 SHEET 7 OF 9

1305 — 600 — 278

1:12,000

Sec. 20, T. 140N., R. 98W
660'S., 660'E. of NW Cor.
0-.15m acceptable for surface. .15-3.0m for subsurface use. 2-4% complex colluvial foot slope with slick spots in area. Salt crystals at .76m. 1.9-2.5m., SAR 15.5 Gyp. -3.9

1300'W., 100'N. of SE Cor.
0-.61m preferred surface material. .61-1.2m acceptable for surface. 1.2-3.0m subsurface material. 2-6% complex side slope with 8-10% slopes on crests. Carbonaceous influence 2.1-2.7m. Salt crystals at 1.1m, 1.5-2.1m., SAR 12.8 Gyp. +4.1

700'S., 100'E. of W1/4 Cor.
0-.30m acceptable surface material. .30-1.1m subsurface use. 1.1-3.0m for use below root zone. 2-4% complex side slope with scattered fractured rock on surface. Coal like material at 1.1m. Acid influence from 1.1-1.8m improved from leaching. Profile is nonrepresentative of materials over coal.

Sec. 32, T. 140N., R. 98W
550'N., 200'W. of E1/4 Cor.
0-.15m preferred surface material. .15-2.1m for use below root zone. 0-2% complex residual bottom. .15-.91m weathered shales with salt crystals.

700'E. of W1/4 Cor.
0-.15m acceptable for surface. .15-.61m for subsurface use. .61-3.0m for use below root zone. 0-2% complex colluvial bottom with numerous slick spot influence. Water table at 1.5m. Salt crystals at .65m.

1300'N., 100'E. of W1/4 Cor.
Refer to Point Site #8 Land Characterization Description.

300'N., 100'E. of SW Cor.
0-.91m preferred surface material. .91-1.2m accetable for surface. 1.2-3.0m subsurface material. 0-2% complex colluvial bottom adjacent to a meandering stream. Water table at 3.0m.

1000'N., 200'E. of W1/4 Cor.
0-.30m preferred surface material. .30-.61m acceptable for surface use. .61-3.0m for use below root zone. 2-4% complex colluvial side slope adjacent to a gentle high.

500'N., 100'E. of SW Cor.
0-.15m acceptable surface material. .15-1.2m subsurface material. 1.2-3.0m for use below root zone. 2-4% complex side slope on gentle hirh. Coal like material at 2.7m. Semi-consolidated shales at 2.1m. Salt crystals at .65m.

Sec. 28, T. 140N., R. 98W
100'N., 100'W. of E1/4 Cor.
0-.15m. preferred surface material. .15-.76 m subsurface material. .76-3.0m use below root zone. 2-4% complex foot slope. Free water at shale line. .45-.76m., SAR 11.2

Sec. 30, T. 140N., R. 98W
1000'N., 50'W. of S1/4 Cor.
0-.15m acceptable surface material. .15-.91m subsurface use. .91-3.0m for use below root zone. 2-4% nearly level to gently sloping surface. Profile located midway on gentle rise.

1250'S., 100'E. of W1/4 Cor.
0-.30m preferred surface material. .30-3.0m for use below root zone. 2-4% complex colluvial foot slope. Acid influence at 2.4-3.0m. The oH on 1:5 leached is 6.7. .30-.61m., SAR 15.8 Gyp. +3.9

1000'W., 600'S. of NE Cor.
0-.30m acceptable for surface use. .30-1.5 for subsurface use. 1.5-3.0m for use below root zone. 2-4% complex foot slope with 6-8% side slopes in area. Salt crystals at .25m.

600'N., 500'W. of SE Cor.
0-.15m preferred surface material. .15-1.5m subsurface material. 1.5-3.0m for use below root zone. 2-4% complex foot slope over weathered shales at .76m. .45-.76m., SAR 5.6

1000'W., 150'N. of S1/4 Cor.
0-.15m acceptable for surface use. .15-.76m for subsurface use. .76-3.0m for use below root zone. 2-4% complex gently sloping swale. Profile located midway on slope. Slick spots in area. Percentage slick soots increasing on lower levels. .76-1.1m., SAR 6.7

250'S., 100'E. of W1/4 Cor.
0-.15m acceptable for surface. .15-3.0m for use below root zone. 2-4% complex slopes near crest of sandy shale high. 8-10% side slopes in area. Depth to shales vary from .15-1.65m.

Depth	SAR	Gyp.
0-.15m	16.3	+2.2
1.6-2.2m	14.1	

1100'W., 1000'N. of E1/4 Cor.
0-.15m acceptable for surface. .15-.61m for subsurface use. .61-3.0m for use below root zone. 2-4% complex colluvial swale below 4-8% gentle crests. Water table at 1.6m. Salt accumulations from .67-1.6m.

1200'N. of S1/4 Cor.
0-.30m preferred surface material. 0-2% complex colluvial material with 4% slopes in area. Degraded solonetz spots in area. Salt crystals 1.2m. Profile adjacent to low area.

800'E., 800'N. of W1/4 Cor.
0-.91m material for subsurface use. Surface material will have to be borrowed. 0-2% complex slopes with micro depressions in area. Standing water in low area. Profile wet.

2300'S., 100'W. of N1/4 Cor.
0-.30m preferred surface material. .30-.76m acceptable for surface use. 2-4% complex colluvial foot slope. Salt crystals at 1.2m. .76-1.2m., SAR 7.9

200'W. of E1/4 Cor.
0-.15m preferred surface material. .15-1.1m subsurface material. 1.1-3.0m for use below root zone. 2-4% complex side slopes with slick soot influence. .61m stratified CL and Clay. Water table 2.1m. Weathered shales and salt crystals at .61m.

900'S. of N1/4 Cor.
0-.91m preferred surface material. .91-3.0m acceptable for surface use. 2-6% complex side slope profile located midway on slope. Crests .15m to sandy shales. Swales deep. Heavy shale material at 1.1m. Stratified soft sandy material at 2.2m.

600'S., 400'W. of N1/4 Cor.
0-.76m preferred surface material. .76-1.2m acceptable for surface use. 1.2-1.6m subsurface material. 2-4% complex side slope with 4-6% slones in area. Thin horizon of coal like shale at 1.6m. 1.2-1.6m., SAR 9.2

* EXPLANATION

LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant media deficiency — Topographic deficiency — aq — Informative symbols
SURFACE LAYER — Quality — Depth
SECOND LAYER — Quality — Depth
Divides soil material and nonsoil material

INFORMATIVE SYMBOLS

OVERBUROEN DEFICIENCIES (for plant media)

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)

TOPOGRAPHIC OEFICIENCIES

- g Slope (including gradient and complexity)
- r Cobbly, stony, flaggy or clinkers (land surface)
- c Cover

SOIL PROFILE NOTES

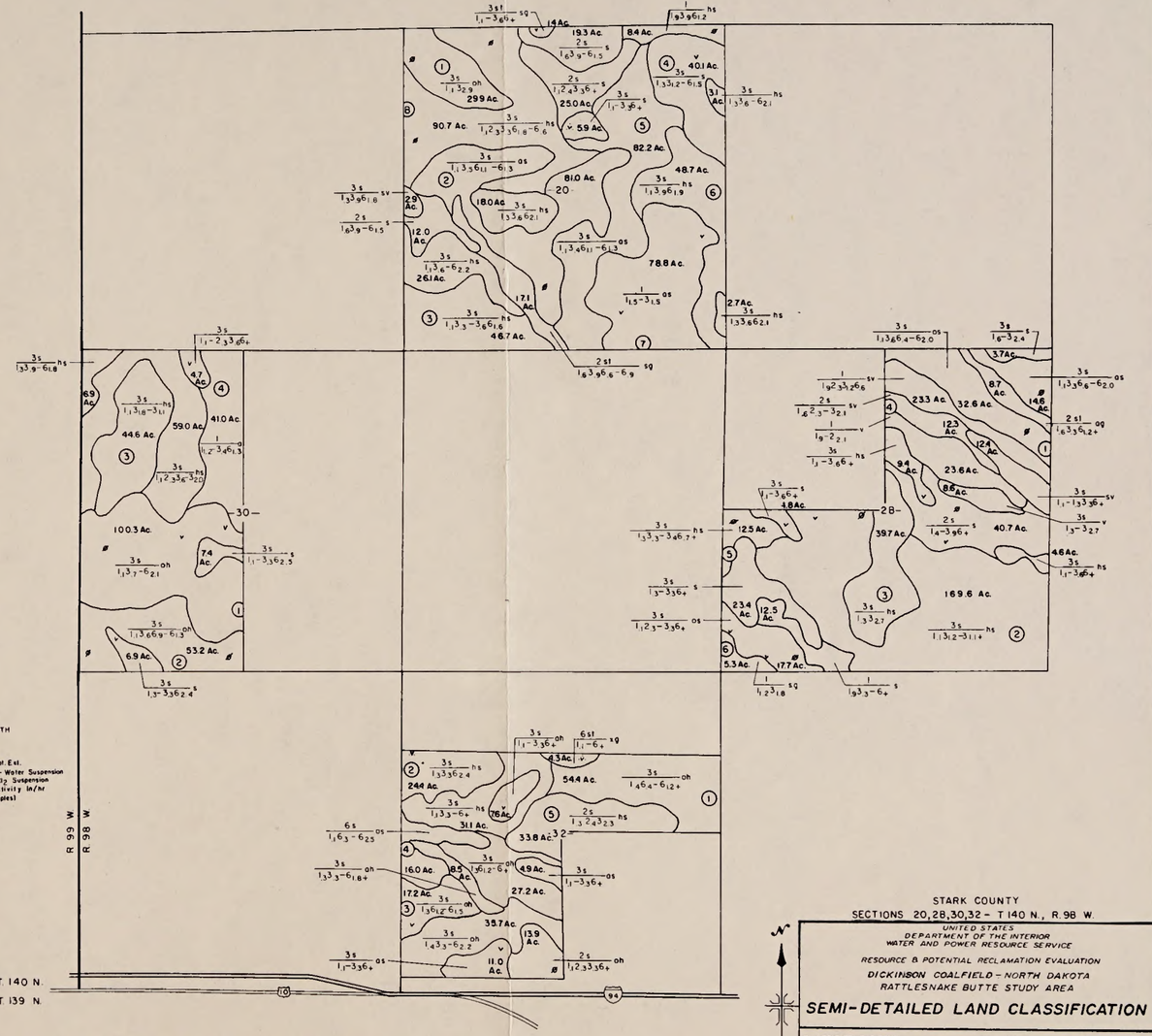
PROFILE REPRESENTS 3.0MDEPTH
SOIL PROFILE NUMBER

CL — 2.8--- 2.8 EC mmhos/cm Sat.Ext.
8.4-8.0 — 8.4 pH 1:5 Soil-Water Suspension
8.0 pH Soil-CaCly Suspension
.65 — .65 Hydraulic Conductivity in/hr (Disturbed Samples)
Li C — 24 Settling Volume
Gr

SOIL PROFILE SYMBOLS

Co	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Li	Light
M	Medium
H	Heavy

* Depths listed are in meters. Multiply by 3.28 to obtain feet



STARK COUNTY
SECTIONS 20,28,30,32 - T 140 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCE SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION
DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T. FIECHTL	SUBMITTED
DRAWN L.E. ALLSOP	RECOMMENDED
CHECKED	APPROVED

DILLINGS, MONTANA — SHEET # OF 9 — FEBRUARY, 1979 — 1305-600-279

Sec. 22, T. 1l0N, R. 98W

(1) 800'E. of W1/4 Cor. 0-.45m preferred surface material. .45-1.8m for subsurface use. 1.8-3.0m for use below root zone. 2-4% complex colluvial foot slope. Salt crystals at .6lm.

(2) 900'N., 100'E. of SW Cor. 0-.30m preferred surface material. .30-.6lm acceptable for surface. .6l-3.0m for subsurface use. 2-4% complex side slope with crests being 6-8% general slopes. .6l-.9lm., SAR 9.6

(3) 1200'E., 1000'N. of SW Cor. 0-.30m preferred surface material. .30-.9lm acceptable for surface use. .9l-3.0m for subsurface. 4-6% side slope with sandy shale crests from 6-8%. Crest varies from .15-.45m to sandy shales. Salt crystals at .76m. 1.1-1.6m., SAR 11.7

(4) 1400'N., 400'E. of S1/4 Cor. 0-.30m acceptable surface material. .30-.9lm subsurface material. .9l-3.0m for use below root zone. 2-4% complex side slopes from 8-12%. Shallow to shales average for area.
Depth SAR Gyp
.30-.76m 11.0 +2.1
1.1-1.6m 15.0 +0.4

(5) 1200'S., 400'W. of S1/4 Cor. 0-.30m acceptable surface material. .30-1.8m subsurface material. 1.8-3.0m for use below root zone. 2-4% complex side slopes in gently rolling area. Weathered shales and salt crystals from .6lm. Dark organic influenced clayey shales at 2.1m.

(6) 1100'S., 300'E. of NW Cor. 0-.30m preferred surface material. .30-.76m acceptable for surface. .76-3.0m for subsurface use. 2-4% complex colluvial bottom with some slick spots in area. Salt crystals at 1.5m.

Sec. 26, T. 1l0N., R. 98W

(1) 600'N., 50'E. of S1/4 Cor. 0-.15m preferred surface material. .15-1.1m acceptable for surface use. 1.1-3.0m subsurface use-alkalinity. 2-4% complex colluvial foot slopes. Salt accumulations at 1.1m with sandstone fragments. Coal fragments at 2.7m. 2.0-2.5m., SAR 7.2

(2) 400'W., 350'N of SE Cor. 0-.15m preferred surface material. .15-.76m acceptable for surface use. .76-3.0m subsurface use-slightly saline. 6-10% complex side slope near crest. .6lm semi-consolidated shales, stratified. Salt crystals at 1.1m. Coal fragments 2.3-2.7m. .76-1.1m., SAR 12.7

(3) 400'N., 300'W. of E1/4 Cor. 0-.30m preferred surface material. .30-.6lm acceptable for subsurface use. 2-4% complex colluvial swale below shale mounds. Slick spot influence in area.

(4) 800'W., 300'S. of NE Cor. 0-.15m preferred surface material. .15-.30m subsurface material. .30-.3.0m for use below root zone. 2-4% complex colluvial foot slope. Salt crystals .46-1.5m. Consolidated sandstone at 2.1m. .30-.76m., SAR 25.6

(5) 1700'N., 900'E. of S1/4 Cor. 0-.15m preferred surface material. .15-.3.0m material acceptable for subsurface use. 2-4% complex colluvial foot slope. Stratified shales at 2.0m.

Sec. 34, T. 1l0N., R. 98W

(1) 1100'W., 200'S. of NE Cor. 0-.30m preferred surface material. .30-.6lm for subsurface use. .6l-3.0m for use below root zone. 2-4% complex side slope with short slopes to 6% in area. 2.4m salt crystals. .6l-1.1m., SAR 17.7 Gyp. +0.2

(2) 1000'E., 100'S. of NW Cor. 0-.6lm preferred surface material. .6l-1.5m subsurface use 15-3.0m use below root zone. 6-8% gentle high areas. .9l-1.5m weathered shales. 1.5-2.1m consolidated sandy shales. .9l-1.5m salt crystals. 2.1m crude coal.

(3) 1200'S. of N1/4 Cor. 0-.30m acceptable for surface use. .30-1.2m subsurface material. 1.2-3.0m not acceptable for root zone. 2-4% complex colluvial side slope. Salt crystals at .30m. Consolidated sandy shales at 1.8m. Profile on better site for area-50% slick spots. 1.8-2.1m., SAR 18.5 Gyp +3.6

(4) 1000'W., 150'N. of E1/4 Cor. 0-.46m preferred surface material. .46-1.5m acceptable for subsurface use. 2-6% complex alluvial channeled bottom. Water table at 1.5m.

(5) 600'W., 300'S. of E1/4 Cor. 0-.6lm preferred surface material. 2-4% complex slope at base of a gently sloping high area. .6lm dense heavy clay shales.

(6) 800'N., 800'W. of SE Cor. 0-.15m acceptable for surface use. .15-.76m subsurface material. .76-3.0m not suitable for root zone. 0-2% complex colluvial slick spot area. .76-1.2m weathered clayey shales. .76-1.2m., SAR 15.5 Gyp. +2.5

(7) 1300'N. of S1/4 Cor. 0-.6lm preferred surface material. .6l-.9lm subsurface material. 0-2% complex alluvial material with slopes along draw from 6-8% in area. Salt crystals at 1.2m.

(7) 1100'E., 500'N. of SI/4 Cor. Refer to Point Site #7 Land Characterization Description.

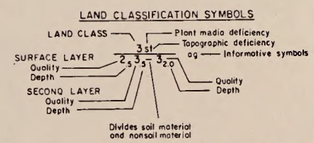
(7) 500'E. of W1/4 Cor. 0-.15m acceptable for surface use. .15-.9lm subsurface use-moderately saline. .9l-3.0m for use below root zone. 2-6% complex side slope with shales outcroping in area. .30-.46m carbon int. clerk. SiC. .46m sandy shales, stratified. .9l-1.5m., SAR 12.9 Gyp. +6.3

(8) 450'E., 250'S. of NW Cor. 0-.30m preferred surface material. .30-1.5m acceptable for surface use. 1.5-3.0m subsurface material. High areas vary from a FSL-L surface. Low areas L-CL. Profile taken on side slope. 1.7-2.1m., SAR 8.1



EXPLANATION *

LAND CLASSIFICATION SYMBOLS



INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES
(for plant media)

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- g Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Cobbly, stony, flaggy or clinkers (land surface)
- c Cover

SOIL PROFILE NOTES.

PROFILE REPRESENTS 30MDEPTH
SOIL PROFILE NUMBER

3 / C L / 2.8-- 2.8 EC mmhos/cm Sat.Ext. 8.4-8.0 8.4 pH 1:5 Soil-Water Suspension 8.0 pH Soil-CaCl2 Suspension / .65 Hydraulic Conductivity in/hr (Disturbed Sample) / .65/24 / Li C / 24 Settling Volume / Gr

SOIL PROFILE SYMBOLS

Co	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
St	Sandstone
F	Fine
Li	Light
M	Medium
H	Heavy

* Depths listed are in meters. Multiply by 3.28 to obtain feet.

STARK COUNTY
SECTIONS 22,26,34 - T. 140 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCE SERVICE
RESOURCE & POTENTIAL RECLAMATION EVALUATION
DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

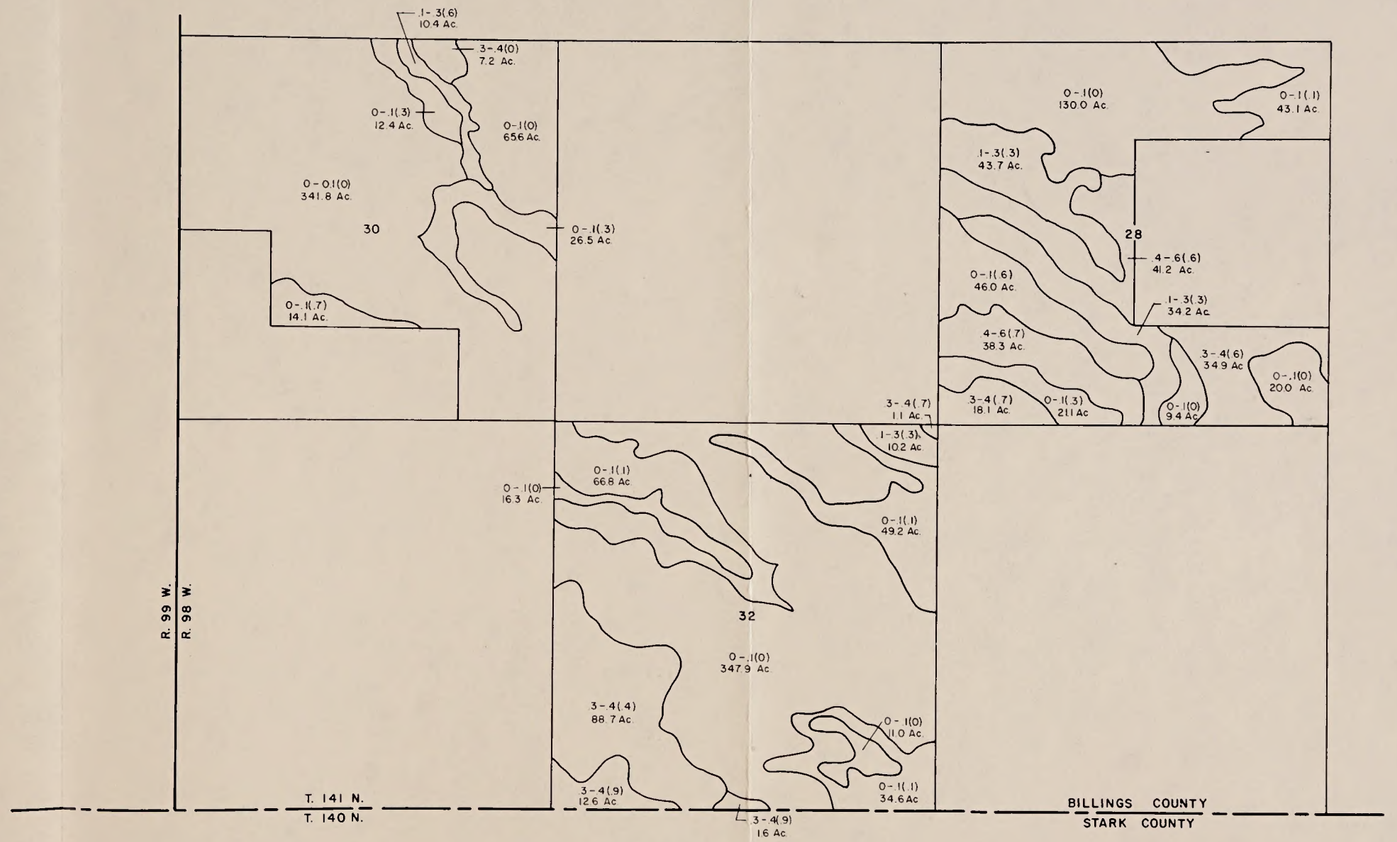
SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T. FIECHTL — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY, 1979 SHEET 9 OF 9

1305-600-280

1:12,000



EXPLANATION

* Depth (m) of preferred material — 1-3(.3) — Depth (m) of acceptable material **

10.4 Ac. - Acreage

NOTES

* Preferred material refers to material that is highly desirable for surface placement in a reconstructed profile. It is nonsaline, nonsodic and permeable.

** Acceptable material refers to additional good quality material immediately below the preferred material. This material may contain slightly higher levels of soluble salts or exchangeable sodium than the preferred material. In most cases, mixing of the preferred and acceptable materials should not appreciably change the overall quality of the topsoil.

Multiply meters by 3.28 to obtain feet.

1:12,000

BILLINGS COUNTY
SECTIONS 28,30,32 - T. 141 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

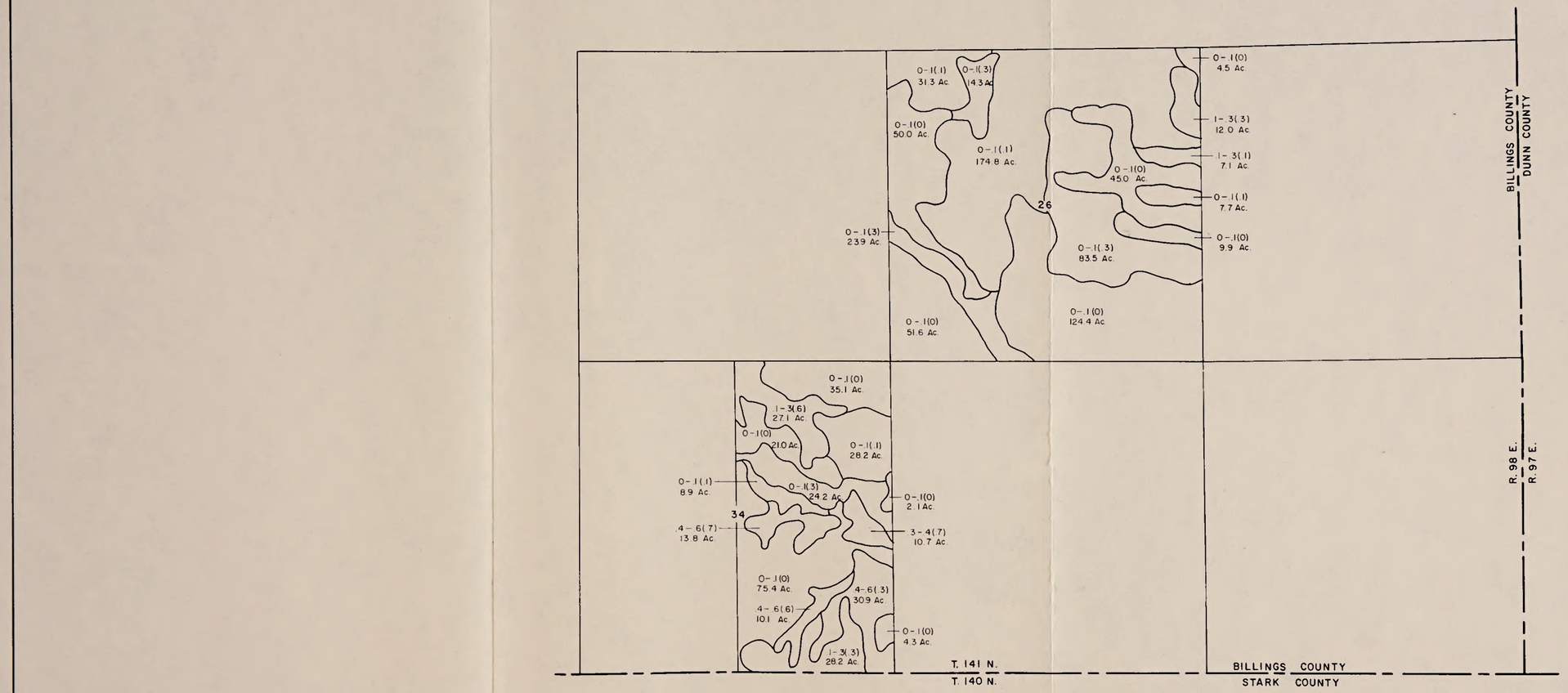
RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

TOPSOILING MATERIAL

CLASSIFIED T. FIECHTL	FIELD APPROVAL
DRAWN L.E. ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED

BILLING, MONTANA — SHEET 1 OF 9 — JUNE, 1981 — 1305-600-281



BILLINGS COUNTY
SECTIONS 26,34, - T. 141 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

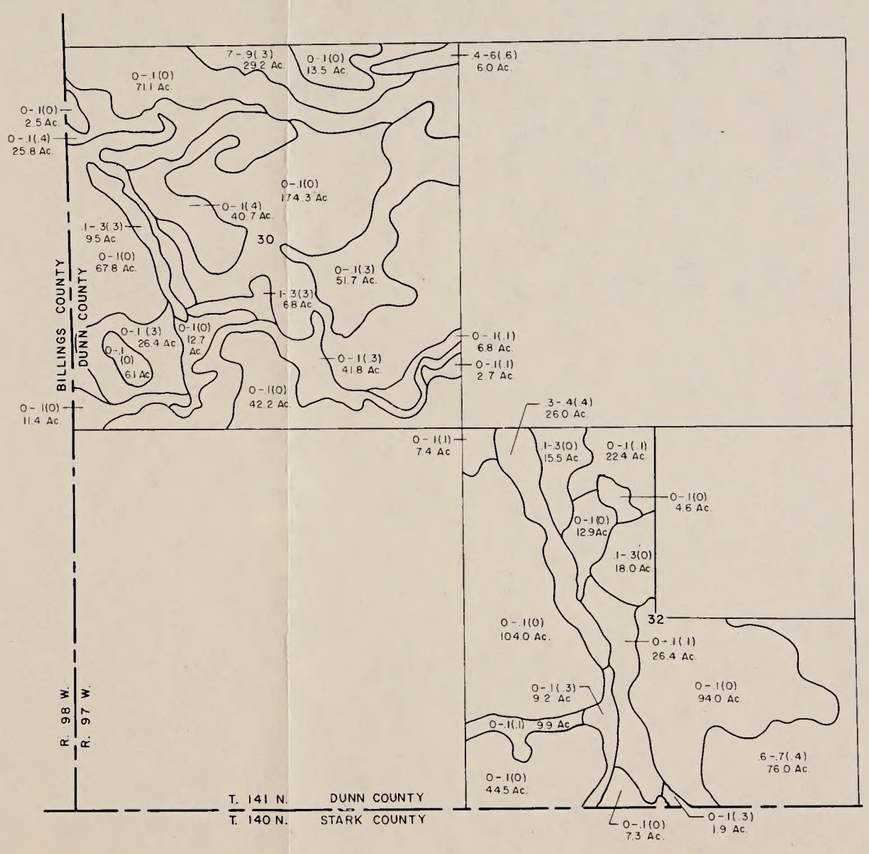
TOPSOILING MATERIAL

CLASSIFIED T. KIECHTL	FIELD APPROVAL
DRAWN L E ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED

BILLINGS, MONTANA SHEET 2 OF 9 — JUNE, 1981 — 1305-600-282

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NOTE
For EXPLANATION see Sheet 1 of 9, Dwg. No. 1305-600-281



DUNN COUNTY
SECTIONS 30,32 T. 141 N., R. 97 W.

NOTE
For EXPLANATION see Sheet 1 of 9, Dwg. No. 1305-600-281

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

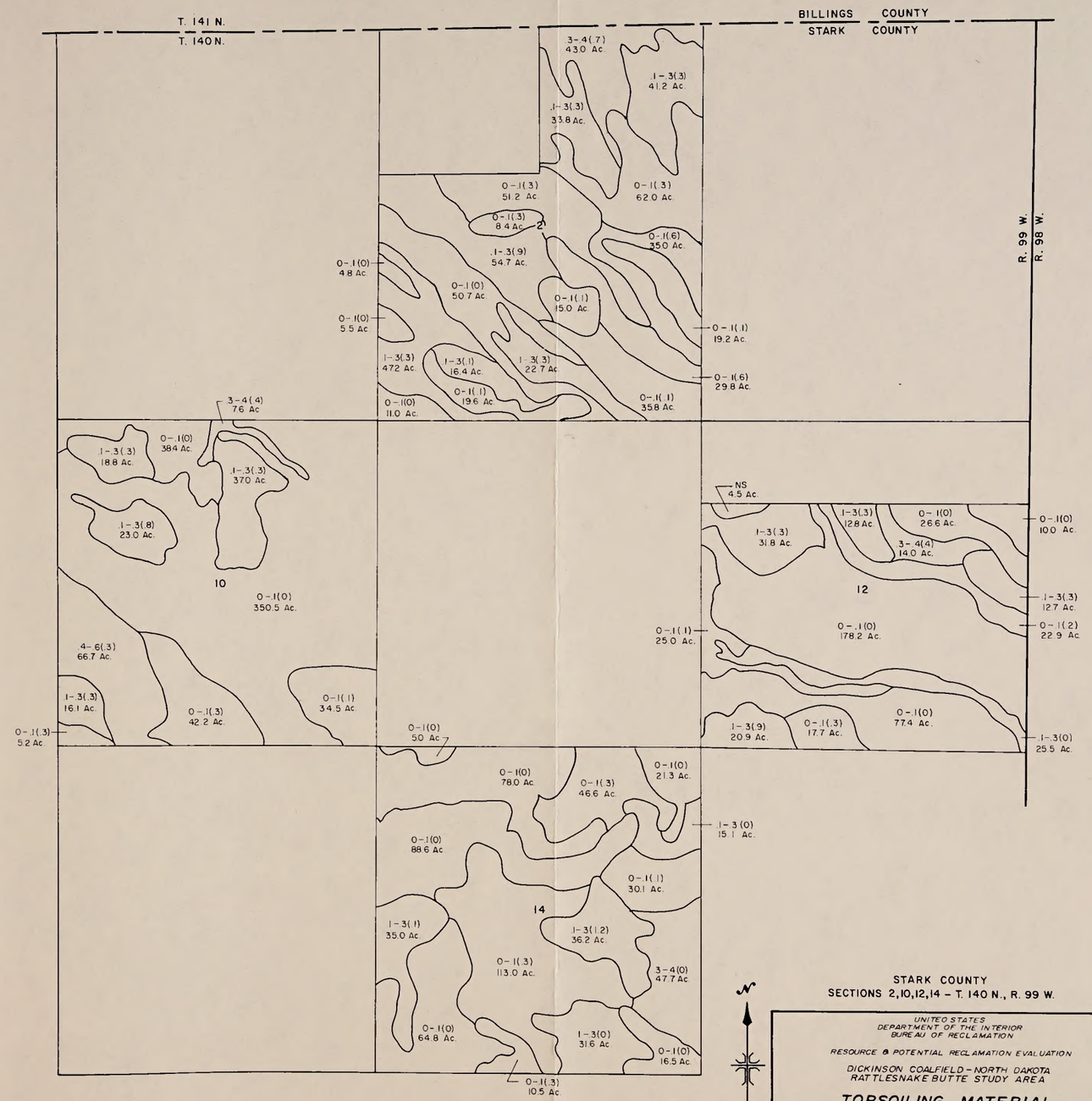
DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

TOPSOILING MATERIAL

CLASSIFIED T. FIECHTL	FIELD APPROVAL
DRAWN L.E. ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED

BILLINGS, MONTANA — SHEET 3 OF 9 — JUNE, 1981

1305-600-283



NOTE
For EXPLANATION see Sheet 1 of 9, Dwg No 1305-600-**281**

1:12,000

STARK COUNTY
SECTIONS 2,10,12,14 – T. 140 N., R. 99 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

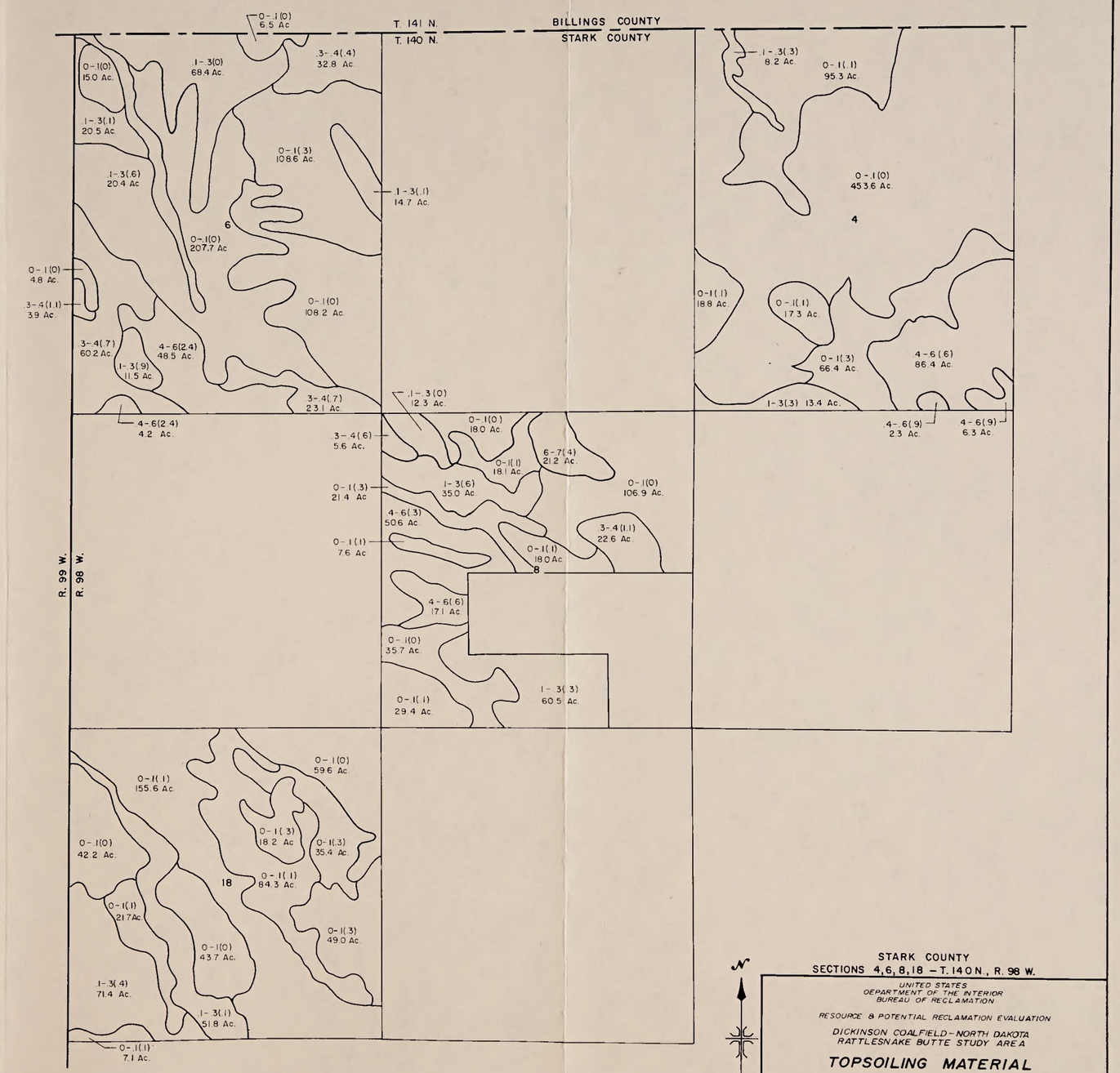
DICKINSON COALFIELD – NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

TOPSOILING MATERIAL

CLASSIFIED T. FIECNTL	FIELD APPROVAL
DRAWN L.E. ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED

BILLINGS, MONTANA — JUNE, 1981 — SHEET 4 OF 9

1305-600-284



NOTE
For EXPLANATION see Sheet 1 of 9 Dwg. No. 1305-600-281

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STARK COUNTY
SECTIONS 4, 6, 8, 18 – T. 140 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

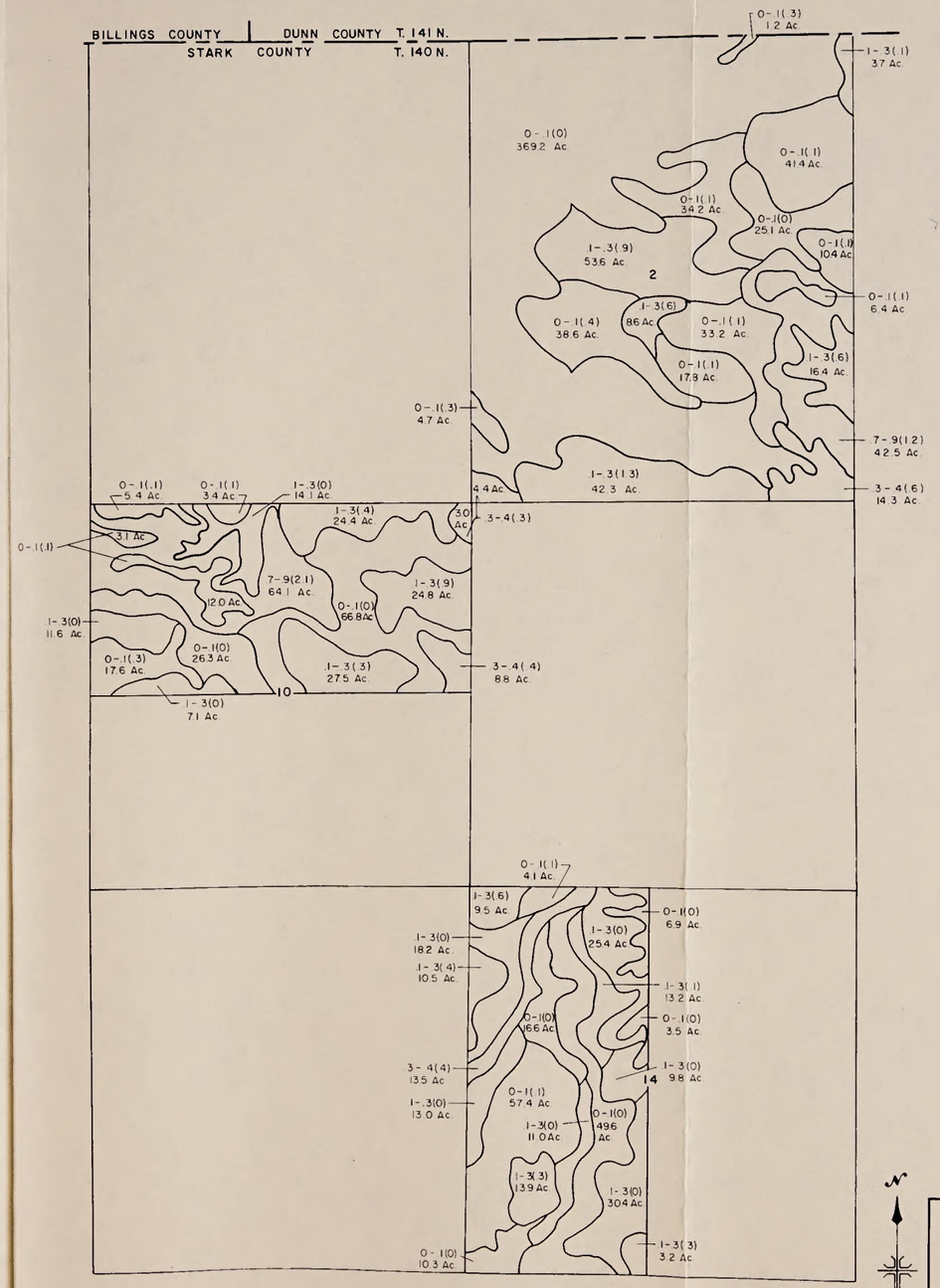
DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

TOPSOILING MATERIAL

CLASSIFIED T. FIECHTL	FIELD APPROVAL
DRAWN L.E. ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED

BILLINGS, MONTANA — JUNE, 1981
SHEET 5 OF 9

1305-600-285



NOTE
For EXPLANATION see Sheet 1 of 9 Dwg. No. 1305-600-281

1:12,000

STARK COUNTY
SECTIONS 2, 10, 14 – T. 140 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

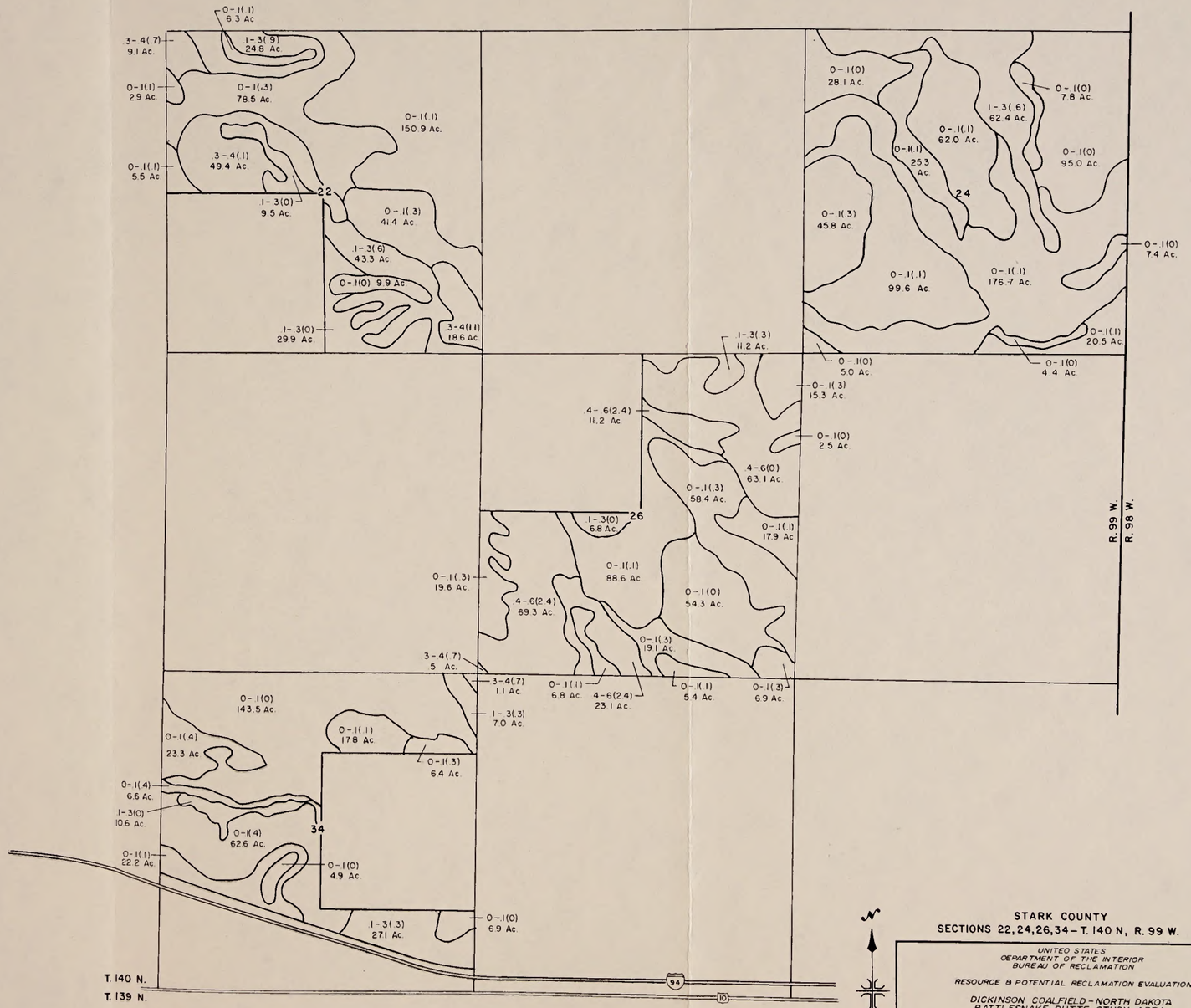
DICKINSON COALFIELD – NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

TOPSOILING MATERIAL

CLASSIFIED T. FIECHTL — FIELD APPROVAL
DRAWN L.E. ALLSOP — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — JUNE, 1981
SHEET 6 OF 9

1305-600-286



NOTE
For EXPLANATION see Sheet 1 of 9 Dwg. No. 1305-600-281

1:12,000

STARK COUNTY
SECTIONS 22, 24, 26, 34 – T. 140 N, R. 99 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

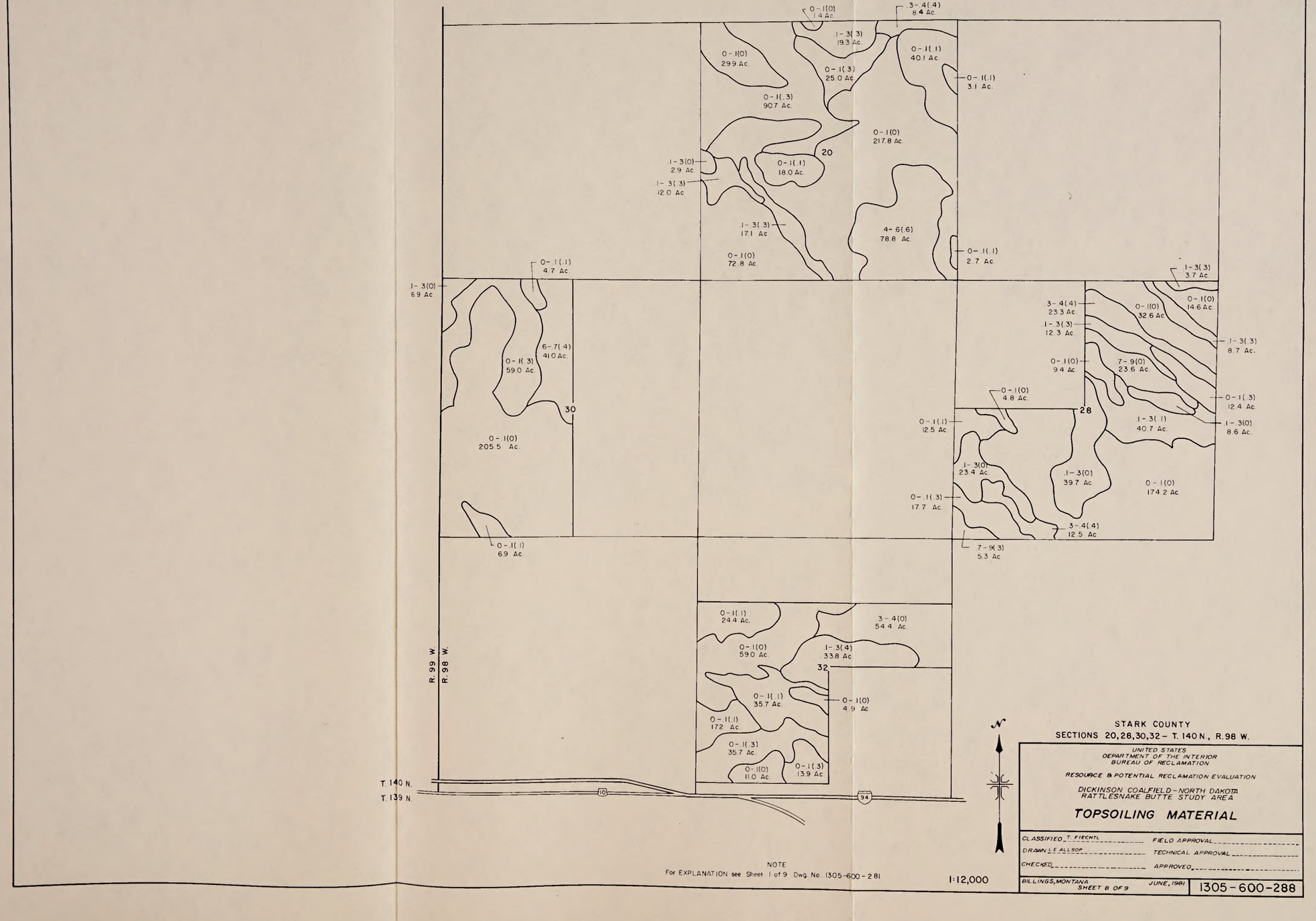
DICKINSON COALFIELD – NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

TOPSOILING MATERIAL

CLASSIFIED T. FIECHTL — FIELD APPROVAL
DRAWN L.E. ALLSOP — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — JUNE, 1981
SHEET 7 OF 9

1305-600-287



NOTE
For EXPLANATION see Sheet 1 of 9 Dwg. No. 1305-600-281

1:12,000

STARK COUNTY
SECTIONS 20,28,30,32 - T. 140 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

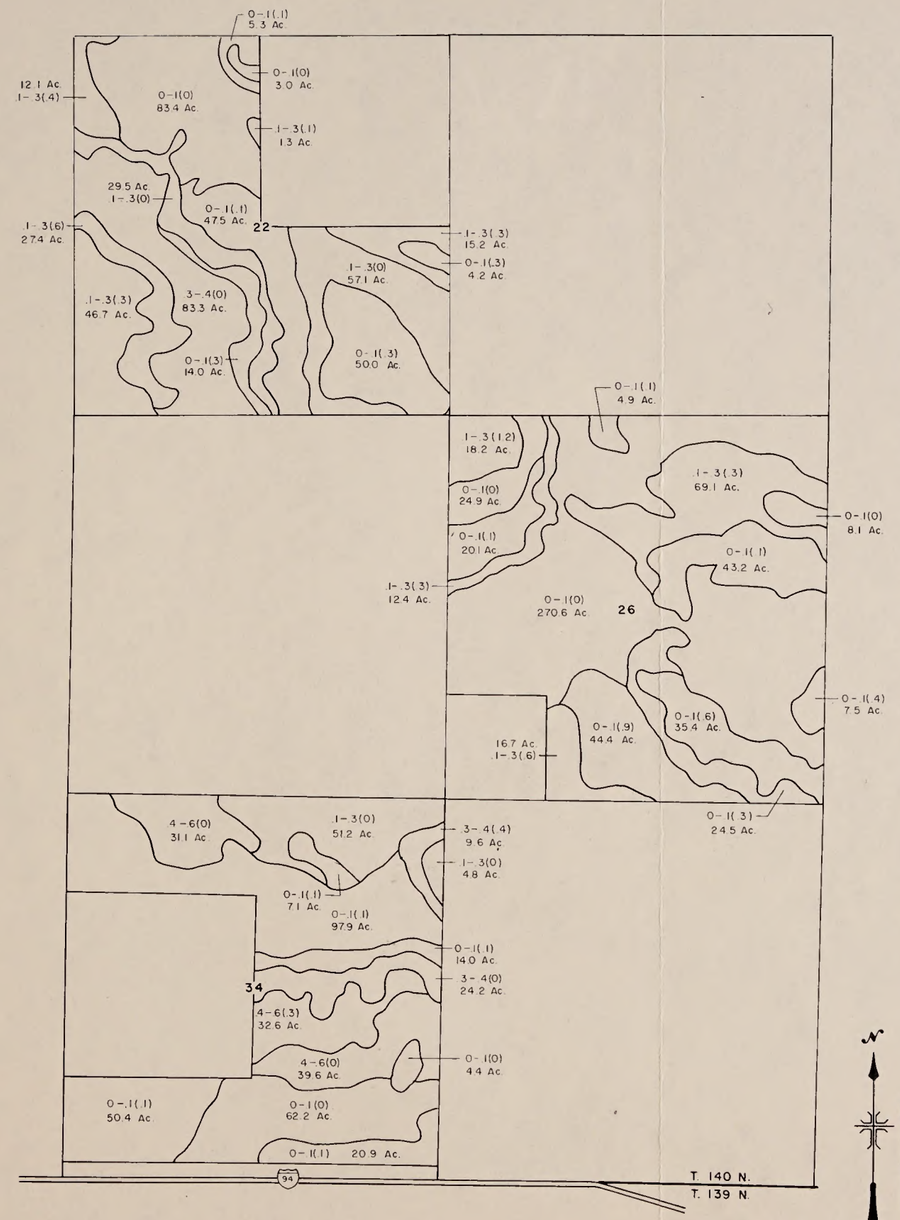
DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

TOPSOILING MATERIAL

CLASSIFIED T. FIECHTL	FIELD APPROVAL
DRAWN L.E. ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED

BILLINGS, MONTANA JUNE, 1981
SHEET 8 OF 9

1305-600-288



NOTE
For EXPLANATION see Sheet 1 of 9 Dwg. No. 1305-600-281

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STARK COUNTY
SECTIONS 22,26,34 - T. 140 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

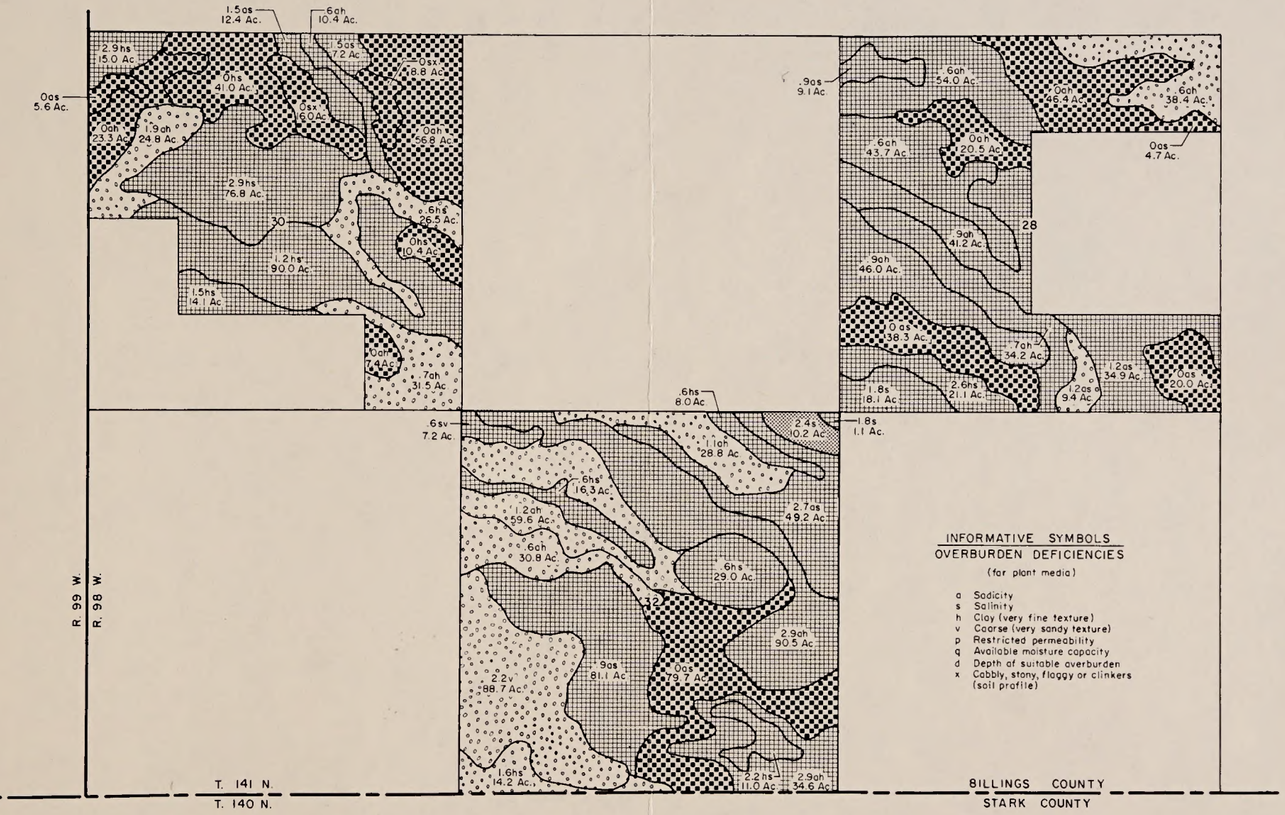
RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

TOPSOILING MATERIAL

CLASSIFIED T. FIECHTL	FIELD APPROVAL
DRAWN L.E. ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED
BILLINGS, MONTANA SHEET 9 OF 9	JULY, 1981

1305-600-289



EXPLANATION

MATERIAL SUITABLE FOR SUBSURFACE PLACEMENT

QUALITY OF MATERIAL

- Good
- Fair
- Poor
- Unsuitable

Depth of Useable Material (m) 1/ — Deficiency

12a

20.0 Ac. — Acreage

NOTES

1/ Additional material immediately below topsoiling material that is suitable for placement below the primary plant root zone. Multiply meters by 3.28 to obtain feet.

1:12,000

BILLINGS COUNTY

SECTIONS 28,30,32 – T. 141 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD – NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SUBSURFACE MATERIAL

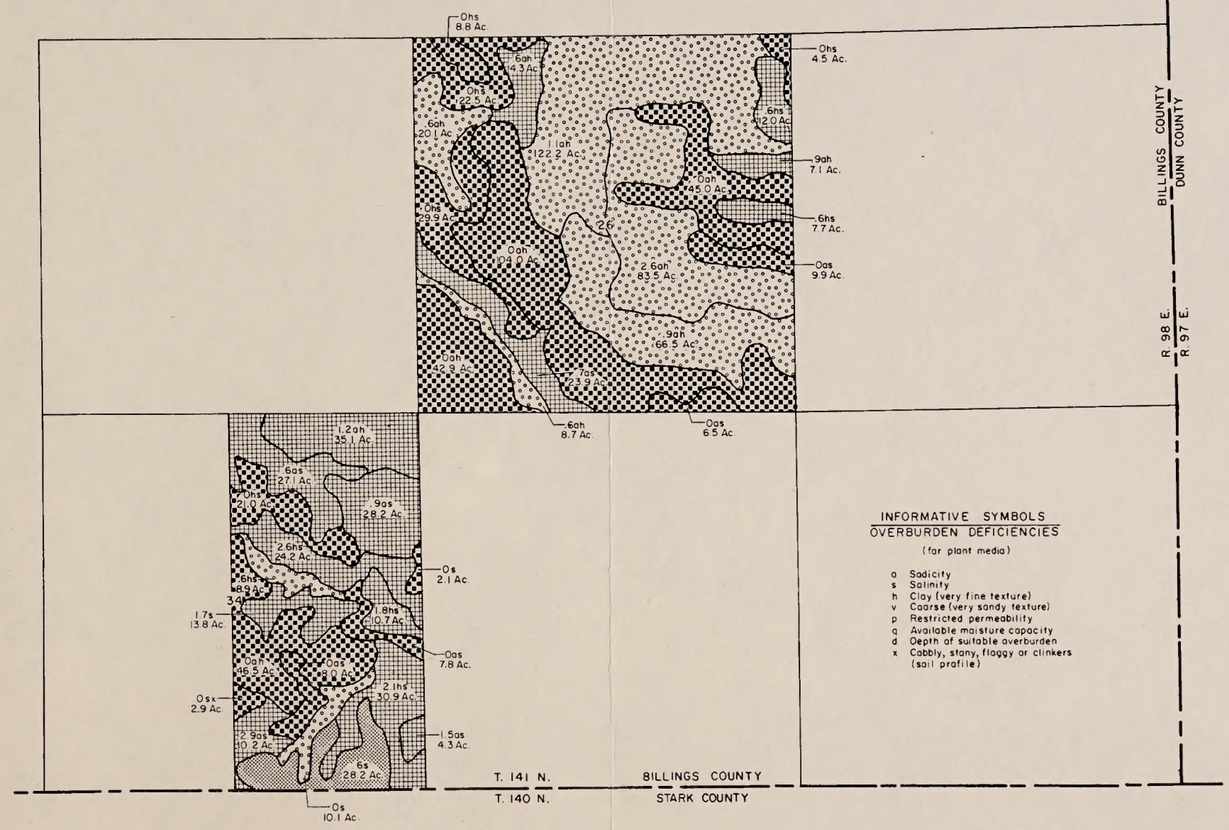
CLASSIFIED T. FIECHTL — FIELD APPROVAL

DRAWN L.E. ALLSOP — TECHNICAL APPROVAL

CHECKED — APPROVED

BILLINGS, MONTANA — OCTOBER, 1981 — SHEET 1 OF 9

1305-600-290



INFORMATIVE SYMBOLS
OVERBURDEN DEFICIENCIES
(for plant media)

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)

EXPLANATION
MATERIAL SUITABLE FOR SUBSURFACE PLACEMENT
QUALITY OF MATERIAL

- Good
- Fair
- Poor
- Unsuitable

Depth of Useable Material (m) 1/ — Deficiency
1.2a
20.0 Ac. — Acreage

NOTES
1/ Additional material immediately below topsoiling material that is suitable for placement below the primary plant root zone. Multiply meters by 3.28 to obtain feet.

1:12,000

BILLINGS COUNTY
SECTIONS 26,34, – T. 141 N., R. 98 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

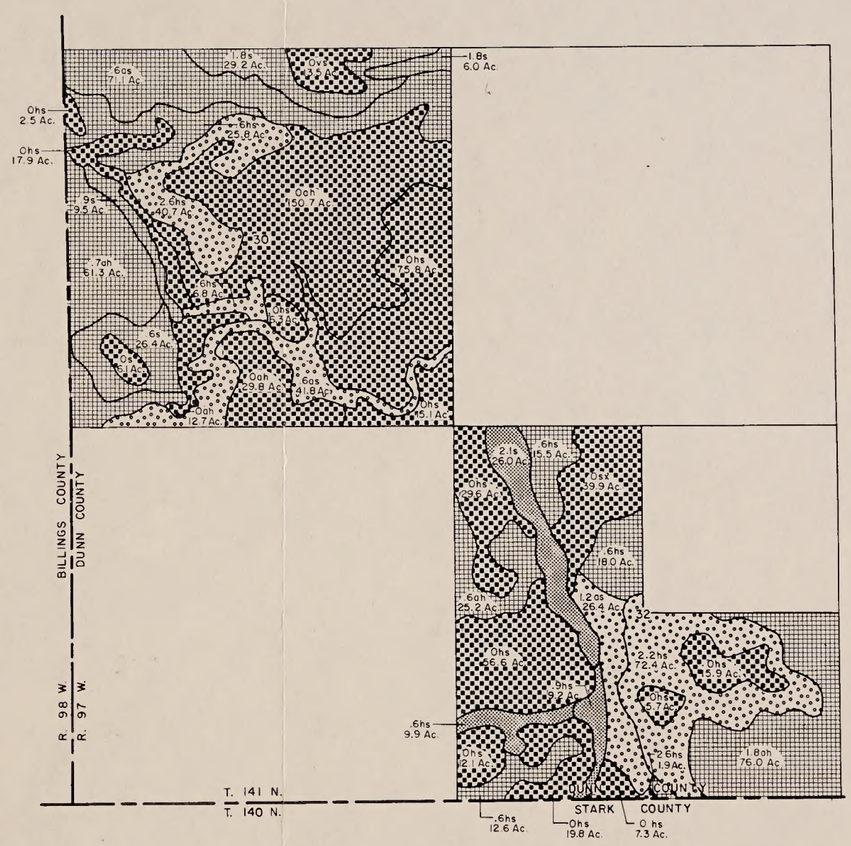
RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD-NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SUBSURFACE MATERIAL

CLASSIFIED T FIECHTL — FIELD APPROVAL
DRAWN G VETTER LE ALLSOP — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — SHEET 2 OF 9 — OCTOBER, 1981 — 1305-600-291



EXPLANATION

MATERIAL SUITABLE FOR SUBSURFACE PLACEMENT

QUALITY OF MATERIAL

- Good
- Fair
- Poor
- Unsuitable

Depth of Useable Material (m) 1/ — Deficiency

1.2o

20.0 Ac. — Acreage

NOTES

1/ Additional material immediately below topsoiling material that is suitable for placement below the primary plant root zone. Multiply meters by 3.28 to obtain feet.

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES

(for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)

1:12,000

DUNN COUNTY

SECTIONS 30,32 T. 141 N., R. 97 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SUBSURFACE MATERIAL

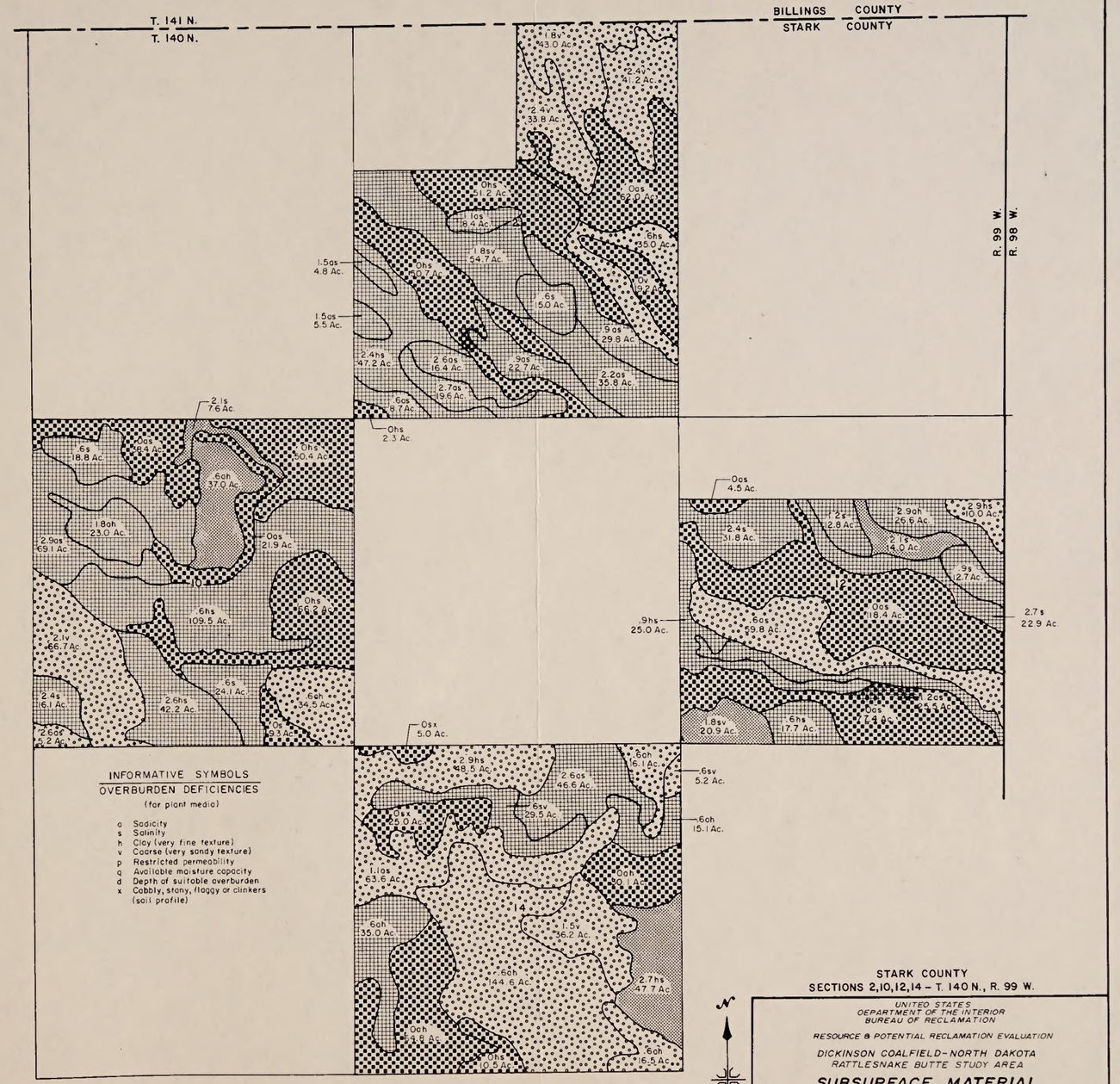
CLASSIFIED T. FIECHTL — FIELD APPROVAL

DRAWN G. VETTER — TECHNICAL APPROVAL

CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY, 1979 SHEET 3 OF 9

1305-600-292



INFORMATIVE SYMBOLS
OVERBURDEN DEFICIENCIES
(for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)

EXPLANATION
MATERIAL SUITABLE FOR SUBSURFACE PLACEMENT
QUALITY OF MATERIAL

- Good
- Fair
- Poor
- Unsuitable

Depth of Useable Material (m) 1/ — Deficiency
1.2o
20.0 Ac. — Acreage

NOTES

1/ Additional material immediately below topsoiling material that is suitable for placement below the primary plant root zone. Multiply meters by 3.28 to obtain feet.

1:12,000

STARK COUNTY
SECTIONS 2,10,12,14 – T. 140 N., R. 99 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

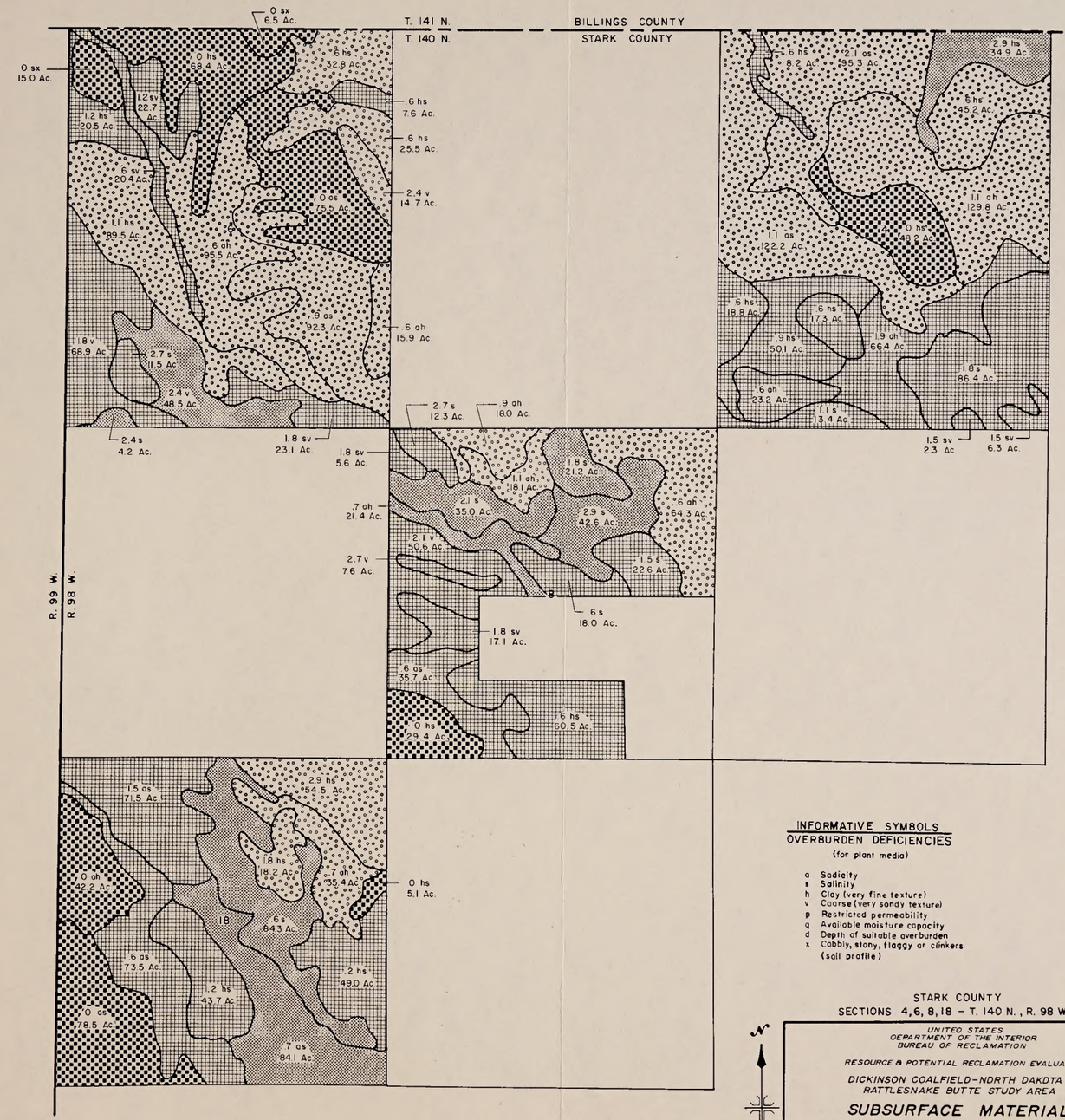
DICKINSON COALFIELD–NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SUBSURFACE MATERIAL

CLASSIFIED T. FIECHTL — FIELD APPROVAL
DRAWN G VETTER — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY, 1979
SHEET 4 OF 9

1305-600-293



EXPLANATION

MATERIAL SUITABLE FOR SUBSURFACE PLACEMENT

QUALITY OF MATERIAL

- Good
- Fair
- Poor
- Unsuitable

Depth of Useable Material (m) 1/ — Deficiency

1.2 a

20.0 Ac. — Acreage

NOTES

1/ Additional material immediately below topsoiling material that is suitable for placement below the primary plant root zone. Multiply meters by 3.28 to obtain feet.

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES

(for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)

STARK COUNTY

SECTIONS 4, 6, 8, 18 – T. 140 N., R. 98 W.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

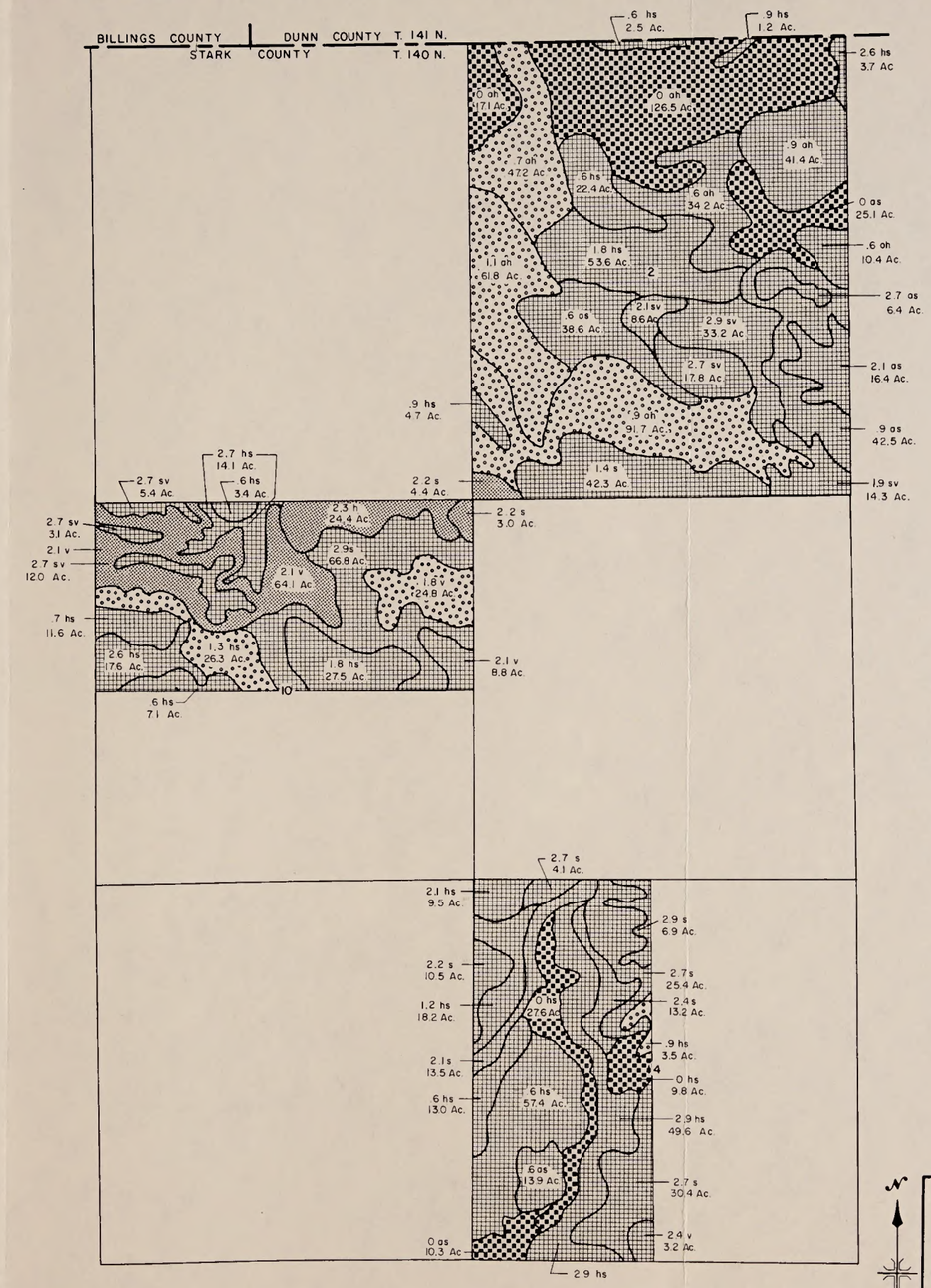
RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD–NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SUBSURFACE MATERIAL

CLASSIFIED T. FIECHTL	FIELD APPROVAL
DRAWN L. E. ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED
BILLINGS, MONTANA SHEET 5 OF 9	JULY 1981

1305-600-294



EXPLANATION

MATERIAL SUITABLE FOR SUBSURFACE PLACEMENT

QUALITY OF MATERIAL

- Good
- Fair
- Poor
- Unsuitable

Depth of Useable Material (m) 1/ — Deficiency

1.2 a

20.0 Ac. — Acreage

NOTES

1/ Additional material immediately below topsoiling material that is suitable for placement below the primary plant root zone. Multiply meters by 3.28 to obtain feet.

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES

(for plant media)

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburen
- x Cobbly, stony, floggy or clinkers (soil profile)

STARK COUNTY

SECTIONS 2, 10, 14 – T. 140 N., R. 98 W.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

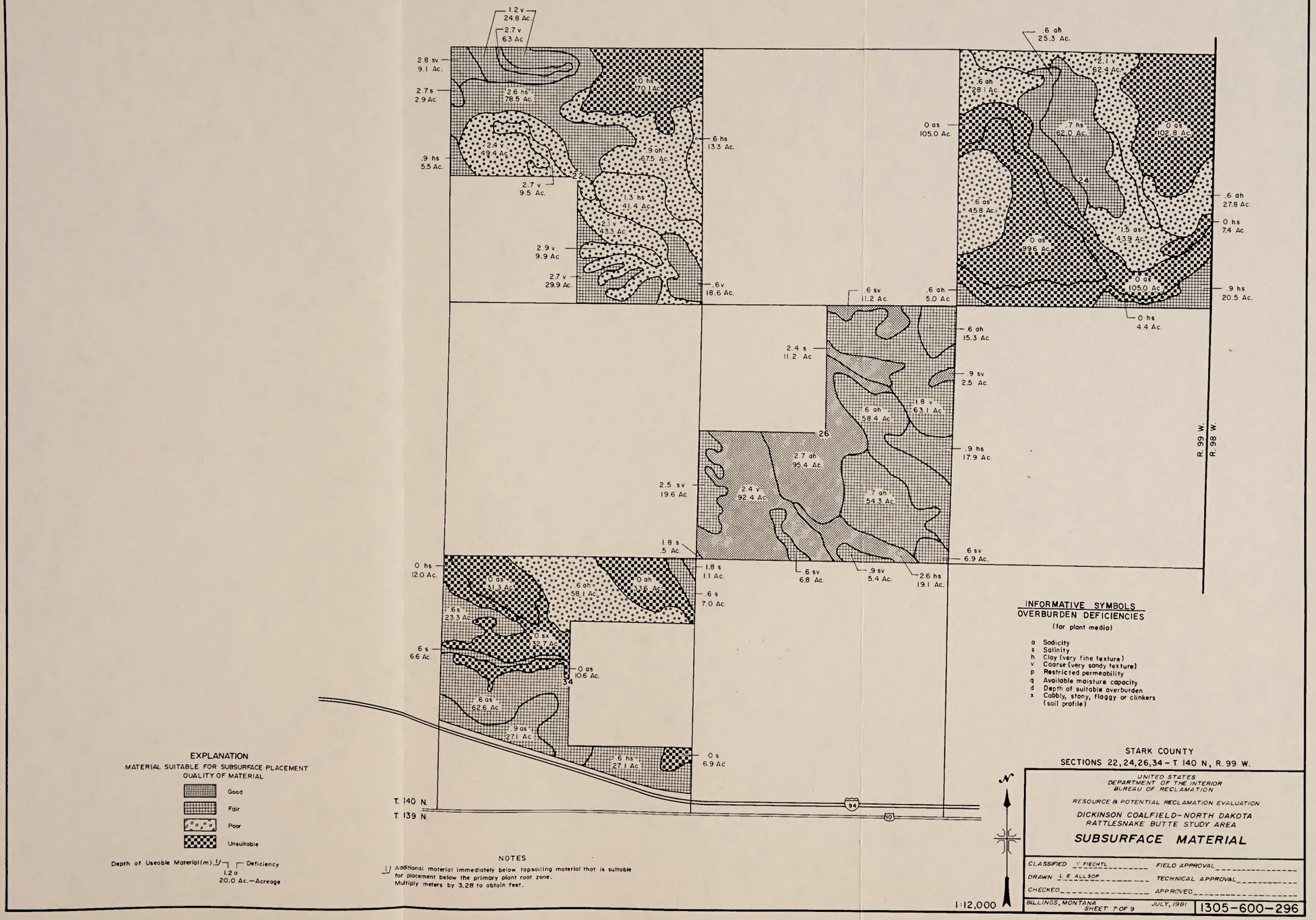
RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD–NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SUBSURFACE MATERIAL

CLASSIFIED T. FIECHTL	FIELD APPROVAL
DRAWN L. E. ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED

BILLINGS, MONTANA SHEET 6 OF 9 — JULY, 1981 — 1305–600–295



INFORMATIVE SYMBOLS
OVERBURDEN DEFICIENCIES
(for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)

EXPLANATION
MATERIAL SUITABLE FOR SUBSURFACE PLACEMENT
QUALITY OF MATERIAL

- Good
- Fair
- Poor
- Unsuitable

Depth of Useable Material(m) 1/ — Deficiency
1.2 o
20.0 Ac.—Acreage

NOTES

1/ Additional material immediately below topsoiling material that is suitable for placement below the primary plant root zone. Multiply meters by 3.28 to obtain feet.

STARK COUNTY
SECTIONS 22, 24, 26, 34 – T. 140 N., R. 99 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

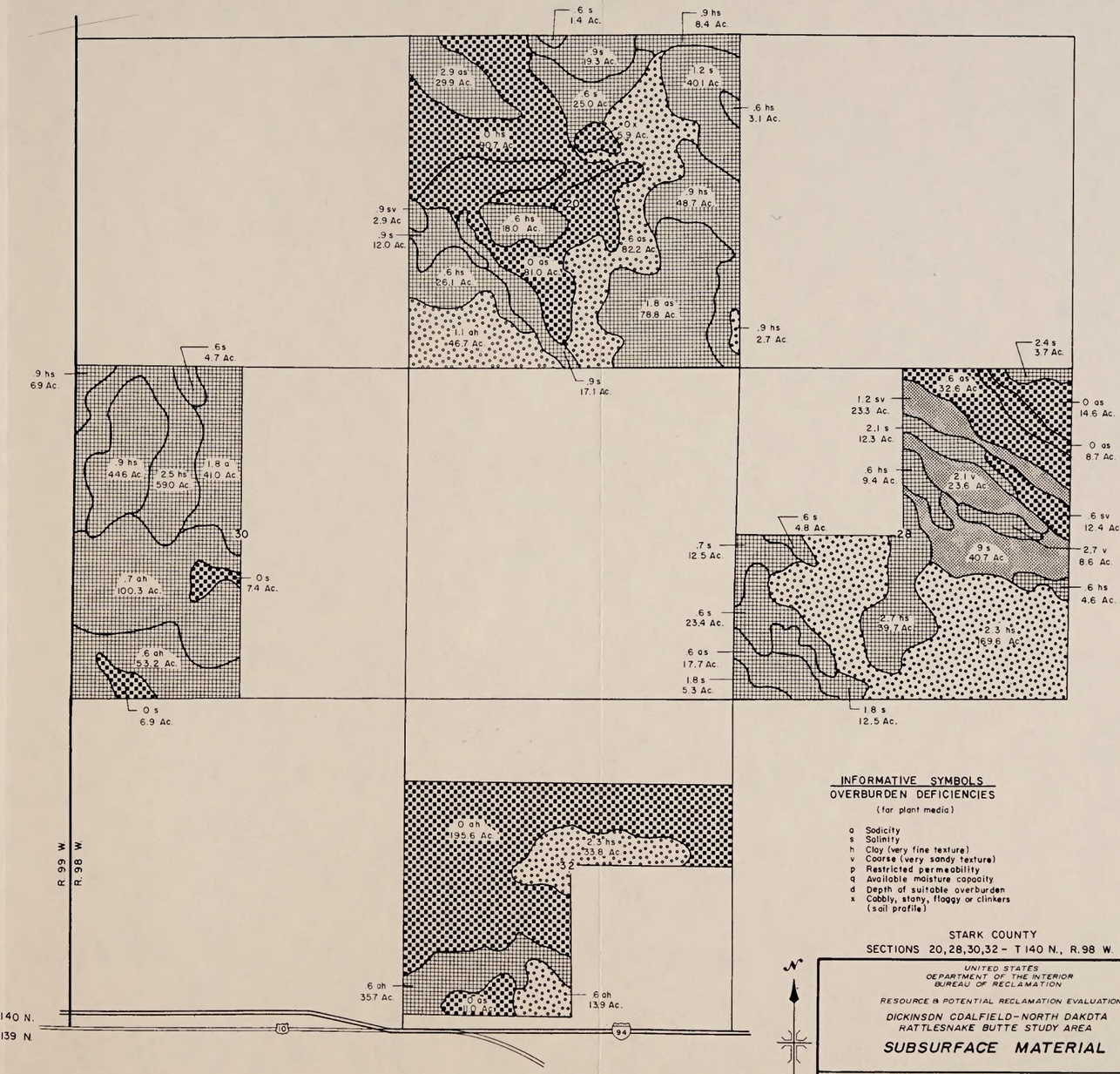
RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD–NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SUBSURFACE MATERIAL

CLASSIFIED V. FIECHTL	FIELD APPROVAL
DRAWN L E ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED
BILLINGS, MONTANA SHEET 7 OF 9	JULY, 1981

1305-600-296



EXPLANATION

MATERIAL SUITABLE FOR SUBSURFACE PLACEMENT

QUALITY OF MATERIAL

- Good
- Fair
- Poor
- Unsuitable

Depth of Useable Material (m) 1/ — Deficiency

1.2 a
20.0 Ac. — Acreage

NOTES

1/ Additional material immediately below topsoiling material that is suitable for placement below the primary plant root zone.
Multiply meters by 3.28 to obtain feet.

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES

(for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)

STARK COUNTY

SECTIONS 20, 28, 30, 32 - T 140 N., R. 98 W.

1:12,000

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

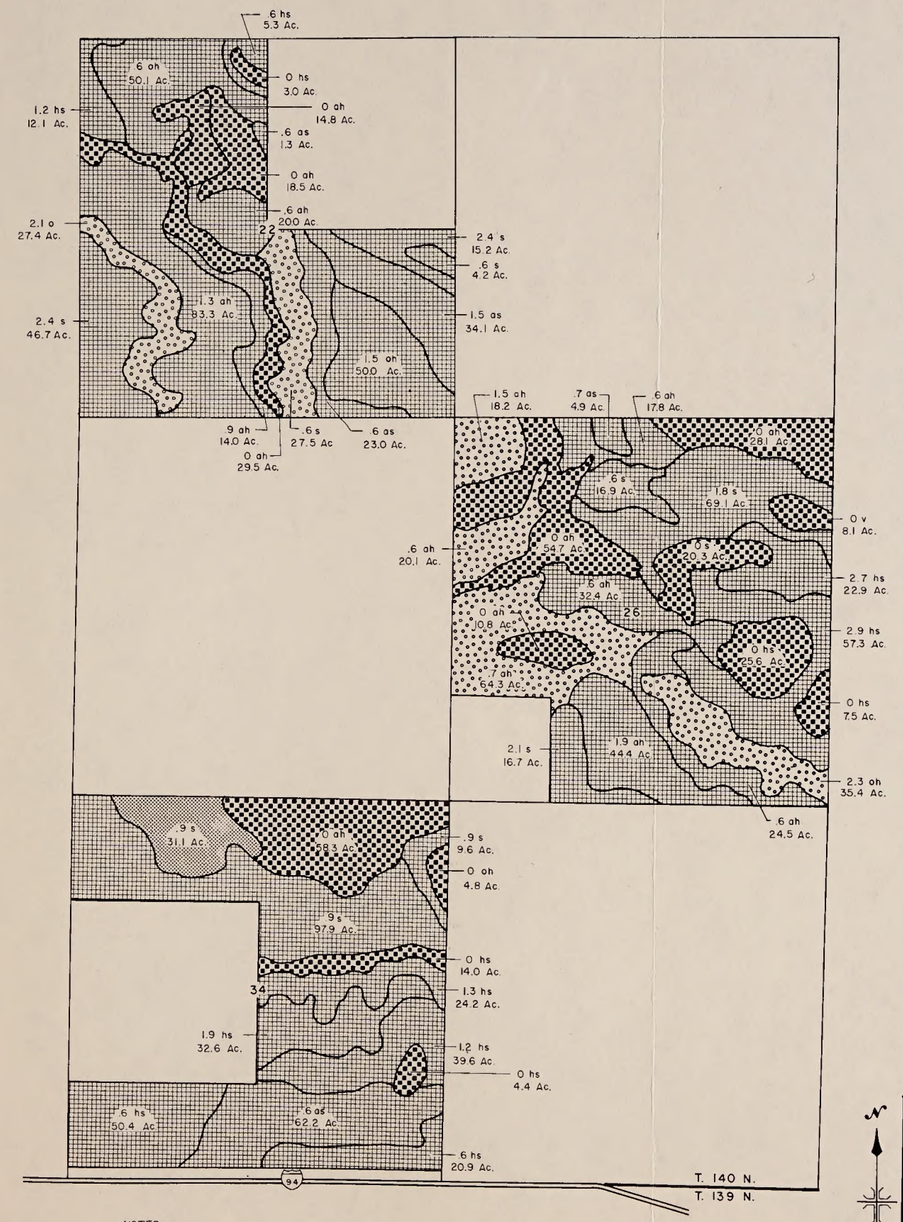
DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SUBSURFACE MATERIAL

CLASSIFIED T FIECHTL	FIELD APPROVAL
DRAWN L E ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED

BILLINGS, MONTANA — SHEET 8 OF 9 — JULY, 1981

1305-600-297



EXPLANATION

MATERIAL SUITABLE FOR SUBSURFACE PLACEMENT

QUALITY OF MATERIAL

- Good
- Fair
- Poor
- Unsuitable

Depth of Useable Material (m) 1/ — Deficiency

1.2 o

20.0 Ac. — Acreage

NOTES

1/ Additional material immediately below topsoiling material that is suitable for placement below the primary plant root zone. Multiply meters by 3.28 to obtain feet.

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES

(for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)

STARK COUNTY

SECTIONS 22,26,34 - T. 140 N., R. 98 W.

1:12,000

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD-NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SUBSURFACE MATERIAL

CLASSIFIED T. FIECHTL	FIELD APPROVAL
DRAWN L. E. ALLSOP	TECHNICAL APPROVAL
CHECKED	APPROVED
BILLINGS, MONTANA SHEET 9 OF 9	JULY 1981

1305-600-298

Rattlesnake Butte, North Dakota

Table 29 - Description of Land Classes

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
1	7.7	Land in this class has an average minimum depth of 36 inches of good or high quality overburden that is suitable for plant media. Usually this material is dark colored soil that has formed on deep alluvial, colluvial, and residual material. Medium texture is most common. Soil aggregates of these medium textured soils have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone. Soil material in this class is high in organic matter, non-saline and nonsodic and there is no indication of toxic material. Below 24 inches the material is moderately calcareous. These lands usually have surplus high quality overburden that is suitable for topdressing or subsoil placement. This material when borrowed will enhance productivity of other tracts.	The surface relief comprises nearly level to gently sloping terraces, fans, foot slopes, and undulating uplands. Most of this land produces small grains and native range. Topographic features will not hinder stripping and stock-piling. Selective stripping can be accomplished easily. Native mid and short grasses are the most common range species.	These soils will be slightly susceptible to wind and water erosion but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.
2s	15.3	Land in this class has an average minimum depth of 18 inches of fair and good quality overburden that is suitable for plant media. Usually this material is largely medium and moderately coarse textured soil that has formed deep colluvial and alluvial deposits and moderately deep residual soils. Textures range from sandy loams to clay loams. Good quality geologic material may be considered as part of the 18-inch requirement. Below 18 inches the overburden is usually calcareous. Soil limitations other than depth include: clay rich layers, reduced moisture retention, restricted permeability, and layers that are saline and sodic. Soil aggregates of these dark colored soils have fair to good stability and water enters the material at a moderate rate. The internal water movement is adequate to provide aeration of the primary plant root zone. Also, adequate moisture is retained for plant use. The material that is suitable for use at or near the surface is nonsaline and nonsodic and there is no indication of toxicity.	The surface relief comprises nearly level to rolling foot slopes, side slopes, swales, and undulating uplands. Topographic features will not hinder stripping and stock-piling desirable material; also, selective stripping can be accomplished easily. Native mid and short grasses are the most common range species. Small grains are the principal dry farmed crops.	Selection of suitable material for use at or near the surface will require a review of the field data. There is adequate topdressing material, but care must be exercised in selecting nonsaline permeable material for the subsoil and substratum. Selective stripping and stock-piling to isolate subsurface material followed by selective placement is necessary for the best use of available material in this land class. With proper selection and placement, reclamation should not be difficult and average management should assure successful permanent revegetation.

Table 29 - Description of Land Classes (Cont'd)

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
2st	2.2	Land in this class has an average minimum depth of 18 inches of good and high quality overburden that is suitable for plant media. Usually this material is dark colored soil that has formed on deep alluvial, colluvial, and residual material. Medium texture is most common. Soil aggregates of these medium textured soils have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone. Soil material in this class is high in organic matter, non-saline and nonsodic and there is no indication of toxic material. Below 24 inches the material is moderately calcareous. These lands usually have surplus high quality overburden that is suitable for topdressing or subsoil placement. This material when borrowed will enhance productivity of other tracts. The most common soil limitations are depth of soil mantle and slowly permeable material in the subsoil and substratum, also salinity and sodicity.	The surface relief comprises moderately steep to strongly sloping and rolling foot slopes. Selective stripping will be difficult and some mixing of surface and subsoil material will occur.	These soils will be slightly susceptible to wind and water erosion but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum. A review of the field data to determine the effect of unavoidable mixing of surface and subsurface material is needed to determine best stripping depths. This will also be a guide for placement in a reconstructed profile.

Table 29 - Description of Land Classes (Cont'd)

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
3s	59.2	Land in this class has an average minimum depth of 10 inches of fair to good quality overburden that is suitable for plant media. Usually this material is largely medium to moderately fine textured soil that has formed on alluvial, colluvial, and residual deposits. The principal limiting soil factor is the limited quantity of nonsaline and nonsodic material for use at or near the surface. The subsoil and substratum often contain moderate to high amounts of sodium and large amounts of gypsum. They are saline and sodic. Laboratory tests indicate fair to poor permeability. Land in this class retains a large quantity of water for plant use. The infiltration rate and internal water movement are moderately slow. There is sufficient suitable material for revegetating for rangeland. Extensive borrowing of material would be required for profiles suitable for cultivation.	The surface relief comprises nearly level alluvial terraces and adjacent foot slopes. Topographic features will not hinder stripping and stockpiling desirable material and selective stripping can be accomplished easily. Native mid and short grasses are the most common range species. Some tracts produce mixed grass hay and a few poorly drained tracts grow only salt grass.	For best use of the soil in this class, the surface material must be stripped and stockpiled, and the subsoil and substratum should be placed with the spoil material. Management practices such as vegetative mulch, mechanized roughing, or contour planting will retard erosion and promote leaching of soluble salts below the primary root zone. These measures can increase the effective leaching of soluble salts and increase production capability. Successful permanent revegetation can be accomplished, but above average planning and management will be required.
3st	4.4	Land in this class has an average mininum depth of 10 inches of fair to good quality overburden that is suitable for plant media. Usually this material consists of medium and moderately clayey residual soil and/or weathered shaley parent material. The major soil limitation is quantity of nonsaline and nonsodic material. There is adequate suitable material for revegetating for rangeland. Extensive borrowing of material would be required for profiles suitable for dryland. Locally the geologic material is permeable and the soluble salts can be leached. Some clay rich and sodium affected layers will most likely be included in the stockpiled material but this should be held to a minimum.	The surface relief of land in this class is characterized by gentle to moderate slopes below ridges and in hilly complex areas. Moderate slopes will make selective stripping difficult. Native mid and short grasses are the dominant species. This land is used for range.	Selective stripping with emphasis on stripping small tracts of deep soil separately should be considered. In addition to a review of the data, a field check to locate these tracts is advisable. Similar surface treatment of reconstructed profiles as described in 3s should be followed.

Table 29 - Description of Land Classes (Cont'd)

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
6s	1.3	Land in this class has less than 10 inches average depth of fair and good quality overbruden that is suitable for plant media. These soils have formed on old alluvium and residuum. This material is clay rich below the surface layer and is often highly saline and/or sodium affected. One or a combination of the above factors make these soils unsuitable for plant media. Some small tracts with good quality soil occur in this class as inclusions.	The surface relief in this class comprises nearly level to very gently sloping old alluvial terraces and residual foot slopes and benches. Topographic features will not hinder selective stripping and stockpiling. Native mid and short grasses are the dominant range species.	A careful review of the data and field checking to locate the small inclusions of better soil is warranted. This combined with selective stripping can do much to reduce the amount of overburden that must be borrowed or modified. Temporary irrigation, pitting, and gouging basins to increase leaching may adequately modify some material. However, borrowing from nearby deep good quality soil areas will probably be the most economical method of permanent revegetation.
6st	9.9	Lands in this class have less than 10 inches average depth of good and fair quality overburden that is suitable for plant media. These shallow residual soils have formed on weathered shaley material. Sandstone and shale outcrops are common. The underlying residual formation is quite variable in physical and chemical properties, moderately saline, moderately sodium influence, slowly permeable, and clay rich layers are the most common limitations. These limitations occur singly or in combination in most delineated areas in this class. However, small inclusions of deeper surface soils and of permeable nonsaline, nonsodic geologic material are also present in most delineated areas.	The surface relief of land in this class is characterized by strongly to moderately steep hilly lands. Moderate slopes will make selective stripping difficult. The areas may have sandstone and/or shale exposures. Native mid and short grasses are the dominant species. This land is used for range.	Selective stripping with emphasis on stripping small tracts of deep soil separately should be considered. These tracts will require a field check to locate and to determine quantity and quality. Borrow material will be required for successful permanent revegetation. The post mining soil profile and vegetative cover will be an improvement over present conditions. Management practices such as vegetative mulch, mechanical roughing, or contour planting will retard erosion and increase production capability.

TABLE 30

Rattlesnake Butte Study Area

Results of the Land Classification Survey

Land Classes - Acreage

T.140N.,R.98W.	1	2s	2st	3s	3st	6s	6st	Total
Sec. 2	42.5	104.2		618.9	2.4			768.0
4	95.0	21.6		651.4				768.0
6	139.9	79.4		539.7				759.0
8	73.3	129.0		256.3	21.4			480.0
10	94.3	72.5	8.8	144.4				320.0
14	13.5	75.8	17.1	175.7	11.0	16.6	10.3	320.0
18		111.3	84.3	369.1	51.8	18.4	5.1	640.0
20	87.2	56.3	17.1	478.0	1.4			640.0
22		242.7	41.4	119.9	61.2		14.8	480.0
26	57.8	168.2	63.2	279.2	15.4		16.2	600.0
28	64.7	53.0	8.7	353.6				480.0
30	41.0			283.0				324.0
32		47.7		222.0		16.0	4.3	290.0
34		117.3	24.2	298.9	9.6			450.0
T.140N.,R.99W.								
2	78.0	281.6		174.6	72.8			607.0
10	74.3	55.8	23.0	449.2	37.7			640.0
12	34.9	82.3		309.4	53.4			480.0
14	36.2		46.6	497.7	34.5		25.0	640.0
22	60.1	145.0		265.0	9.9			480.0
24	62.4			460.4	105.0	7.8	4.4	640.0
26	23.6	169.4	22.4	262.1	2.5			480.0
34	1.1	141.6	13.6	97.3	29.6	31.3	25.5	340.0
T.141N.,R.97W.								
30	35.2	42.1		446.4	111.3	7.7	6.3	649.0
32	26.0	76.0		322.0	51.4		4.6	480.0
T.141N.,R.98W.								
26		12.0		567.7	23.9	26.5	9.9	640.0
28	59.3	172.2		248.5				480.0
30	10.4			329.0	10.4	97.8	30.4	478.0
32	15.3	98.9		525.8				640.0
34	92.6	28.2		153.3	36.0		9.9	320.0
Total	1318.6	2584.1	370.4	9908.8	742.3	222.1	166.7	15313.0
Percent	8.6	16.9	2.4	64.7	4.8	1.5	1.1	100.0

materials in this study area were classified as fair or poor for placement below the primary plant rooting zone in reconstructed profiles (see Plates 47 through 55).

Permeable material that is slightly to moderately saline may be utilized in areas lacking good quality subsurface material. This material should leach and reclaim readily if placed over spoils with good internal drainage characteristics. Sodic and/or clay-rich materials should be selectively placed well below the plant rooting zone in reconstructed profiles.

Bedrock Suitability

A systematic evaluation was made of the bedrock core materials described in Plates 12 through 26, Appendix B, in order to determine suitability of the materials for use as supplementary plant media.

Complete laboratory analyses, including selected trace element determinations, were performed on samples collected from USBR Drill Holes 78-101 and 102 and 79-103 through 115. The results of these tests are listed in Tables 31 through 45, Appendix D.

The suitability criteria listed in Table 46, Appendix D, were applied to the laboratory data in order to place the bedrock materials into one of three classes: Suitable, Limited Suitability, or Unsuitable.

Table 47, Appendix D, presents a summary of bedrock suitability for use as plant media in the Rattlesnake Butte Study Area. Overall, approximately 3 percent of the bedrock materials overlying the VIII (Fryburg) coalbed in this study area were rated Suitable for use as plant media, 7 percent were of Limited Suitability, and 90 percent were Unsuitable.

In general, most samples collected below 20 to 30 feet in depth contained excessive levels of exchangeable sodium, causing them to be classified as Unsuitable. Several of the cores were highly sodic to the surface. Only two drill holes, 79-112 (0 -34.3 feet) and 79-114 (0 -10.8 feet), had surface samples which were rated Suitable. The Suitable materials were generally fine-grained sandstones or silty shales. In addition to excessive exchangeable sodium, other limiting factors included moderate to high levels of soluble salts, high clay or sand percentages, high pH, and high trace element concetrations. In particular, very high levels of lead were detected in the surface samples from DH-79-104 and DH-79-107.

Ideally, bedrock materials containing excessive levels of soluble salts, exchangeable sodium, and/or trace elements should be covered by a minumum of 4 feet of nontoxic overburden during the reclamation operation in order to alleviate any hazard associated with plant reestablishment. Although topsoil/subsoil quantity and quality appear sufficient for plant reestablishment in this study area, this bedrock suitability evaluation indicates that a 4-foot covering of nontoxic overburden over the entire study area may not be achievable. More detailed premining investigation will be necessary to more accurately quantify the available nontoxic overburden in this study area.

Soil Inventory

This section provides additional data on the soils occurring in the Rattlesnake Butte Study Area. Most of the information is derived from soil survey data compiled by the Soil Conservation Service.[2/]

Data presented in this section include the following:

1. A Soil Inventory Map of the Rattlesnake Butte Study Area showing the soil types/complexes/associations mapped by the Soil Conservation Service - Plate 56, Appendix D.

2. Soil Series Descriptions (National Cooperative Soil Survey) - Tables 48 through 72, Appendix D.

3. Interpretive ratings for selected soil uses - Table 73, Appendix D.

4. Engineering properties of the soils - Table 74, Appendix D.

5. Erosion evaluations (BLM Form 7310-12) correlating with USBR Point Site soil profile descriptions - Exhibit 3, Appendix D.

Note - Soil survey data was unavailable for sections of the study area located in Billings and Dunn Counties; therefore, this data is not included in this report.

2/ Soil Survey of Stark County, North Dakota, USDA - Soil Conservation Service, 1968.

CONCLUSIONS

CLIMATE

The Rattlesnake Butte Study Area has a continental-type semiarid climate characterized by harsh cold winters, warm summers, and large variations in seasonal precipitation.

The mean annual precipitation in this area, recorded at Dickinson, North Dakota, is about 15.5 inches. More than 75 percent of the annual precipitation occurs during the growing season, April through September. June is generally the wettest month, receiving as much as 10 inches.

The average annual maximum and minimum temperatures for this area (recorded at Dickinson) are 54°F. and 28°F., respectively. Generally, about 22 days a year have a maximum temperature exceeding 90°F, but a maximum temperature above 100°F occurs only 2 to 3 days a year, and in some years not at all. Based on data recorded at Dickinson, the average length of the freeze-free period is estimated at 122 days between mid- to late-May and mid-to late-September.

On the average, thunderstorms occur on 30 to 35 days each year, and hail generally falls on 2 or 3 of these days.

Winds that erode unprotected soils occur 34 percent of the time, primarily during April, May, and June.

The area receives about 60 percent of the sunshine that could possibly occur each year.

Most climatic factors in the Rattlesnake Butte Study Area appear favorable for revegetation of surface-mined land with native range plants, small grains, or other adaptable crops. However, several hazardous climatic factors which may adversely affect revegetation efforts in the area should be recognized. These are: (1) below normal or uneven distribution of precipitation, especially during the growing season, (2) severe thunderstorms or hailstorms that cause crop damage and soil erosion, (3) late spring freezes, and (4) soil erosion and moisture depletion by wind.

PHYSIOGRAPHY

The Rattlesnake Butte Study Area lies in the unglaciated Missouri Plateau section of the Great Plains Physiographic Province. This section is characterized by a series of complex, narrow divides which are the eroded remnants of a once widely extensive plateau.

The topography of this study area is variable, ranging from nearly level and gently sloping stream terraces, fans, and footslopes to steep, rolling uplands. Sedimentary strata of the Fort Union Formation (Sentinel Butte Member) are exposed along deeply-incised drainage channels and, to a lesser extent, at higher elevations in the uplands. Resistant scoria (baked shale)

outcrops are common throughout this study area. These outcrops appear as thin remnant caps over gentle and moderately sloping uplands.

The relief in this study area is approximately 260 feet, ranging from 2470 feet along North Creek in the southeast corner of the study area to 2730 feet in the uplands.

Drainage of the study area is accomplished through an extensive network of branching drainages (dendritic pattern). The majority of the area drains southeastward to the Heart River via North Creek and its tributaries. The northern portion of the study area drains in a northwesterly direction toward Green River.

GEOLOGY

The Rattlesnake Butte Study Area lies within the Williston Basin of west-central North Dakota.

Bedrock is of Paleocene Age and belongs to the Sentinel Butte Member of the Fort Union Formation. It mostly consists of soft shale and sandstone with lesser amounts of siltstone and lignite.

Thirteeen lignite and/or lignitic shale beds were penetrated by drilling in the area. Two coalbeds are of primary economic significance. They are the IV and VIII Coalbeds. Both coalbeds vary considerably in thickness from one part of the study area to another and each averages over 8 feet thick. Overburden is generally less than 200 feet thick over each bed.

Engineering property tests were not conducted on bedrock samples from the Rattlesnake Butte Study Area, but results should be similar to those for comparable material at the Otter Creek Study Site, Montana. Those tests revealed that shear strengths of the material are low, especially in a saturated condition. Slides can easily develop adajacent to high walls in surface mines, primarily along beds of weak, plastic, carbonaceous shales. Saturated alluvial deposits and uncemented siltstones and fine grained sandstones will readily erode and flow into excavations.

Excavation slopes will vary between minesites and will be dependent on exposure time, moisture conditions, material types, and depth of cut. Adequate drainage will have to be maintained to relieve pore water pressure in the overburden, and excavation below the water table will be limited until the material is drained.

Studies at the Otter Creek Site indicate that disturbed overburden should have slopes not greater than 4 to 1 and berms of 50 to 100 feet in width designed on the slope surface.

Volume changes in the overburden will occur with disturbance. An increase in volume of about 25 percent should be expected. In some cases, the surface of the replaced overburden will be higher than the ground surface before mining.

Three types of instability are common on reclaimed coal-mined areas in the Northern Great Plains. They are: (1) areawide settling, (2) localized collapse, and (3) piping. Each form of instability is affected by certain variables in the postmining landscape. These variables include the physical and chemical characteristics of the overburden, the methods and equipment used in stripping and contouring operations, and the season when these activities occur. One or more of these types of landscape instability may occur on reclaimed land in the Rattlesnake Butte Study Area.

Weathering tests performed on bedrock samples from the study area revealed that shales break down more rapidly than either sandstones or siltstones, but the material produced may be difficult to move and place because of its plasticity.

Most types of earth materials for construction uses are available in the study area. Only concrete aggregate and high quality riprap will probably have be obtained from outside of the study area.

The Rattlesnake Butte Study Area lies in a stable seismic region, and no significant earthquake damage has been experienced in the past.

COAL RESOURCES

The Rattlesnake Butte EMRIA study site is located in the Dickinson coalfield in the central part of the Williston Basin, southwest North Dakota. This area contains surface-minable resources in threee lignite beds that range in thickness from 1.4 to 18 feet, in the Tongue River and Sentinel Butte Members of the Fort Union Formation of Paleocene Age.

Resources of lignite in the three beds total 484 million tons (439 million metric tons). Of this amount 26 percent or 128 million tons is in beds more than 10 feet thick that are under less than 200 feet of overburden. Measured resources total 55.7 million tons (50.5 million metric tons), indicated resources total 233 million tons (211 million metric tons), and inferred resources total 196 million tons (178 million metric tons).

The apparent rank of the coal ranges from lignite A to lignite B. The average heat of combustion of 19 core samples from the site on the as-received basis is 5600 Btu/lb (3110 kcal/kg), average ash content is 10.6 percent, and average sulfur content is 1.0 percent.

OVERBURDEN - SOIL AND BEDROCK

Soils of the Rattlesnake Butte Study Area can be placed in two major categories based on their mode of development, landform position, and parent material. They are: (1) residual soils on uplands developing in weathered sandstone, siltstone, shale, and baked shale (scoria) and (2) alluvial/colluvial soils on fans, footslopes, swales, and terraces forming in loamy alluvial/colluvial deposits. The soft sedimentary strata of the Sentinel Butte Member, Fort Union Formation, have provided the parent materials for both major soil categories. The residual soils occur over approximately 85 percent of the study area; the alluvial/colluvial soils occupy about 10 percent of the area; and minor soil inclusions, i.e., wind-deposited soils, occur on only 5 percent of the area.

A semidetailed land suitability classification of the Rattlesnake Butte Study Area was made to evaluate and characaterize the overburden (soil and bedrock to a depth of 10 feet) as a source of material for resurfacing and revegetating the study area if it is surface-mined. This survey provides data on the quantity and quality of material for revegetation and ease of stripping and stockpiling the usable material.

Four land classes: 1, 2, 3, and 6 were established to group land of equal suitability for the specific use of revegetation. Class 1 lands provide the most desirable and plentiful source of easily stripped revegetative material. Land in this class may have surplus suitable material that can be utilized in deficient areas. Class 2 lands have adequate supplies of resurfacing material, but it is generally of lower quality than Class 1 or somewhat more difficult to strip. Class 3 lands are marginally suitable, but can generally meet the planting media needs for their revegetation. Class 6 lands lack adequate supplies of suitable material to meet the needs for revegetation. If these lands are disturbed by surface mining, it will be necessary to borrow material from areas with adequate supplies or modify the material available for revegetation.

The results of the land suitability classification of the Rattlesnake Butte Study Area expressed as a percentage of the area are as follows: Class 1- 8.6, Class 2 -19.3, Class 3 - 69.5, and Class 6 - 2.6.

Based on the field and laboratory data obtained from the land suitability classification, it appears that most of the residual and alluvial/colluvial soils in this study area should yield about 6 to 12 inches (.15 to .30 m) of good quality topsoiling material for revegetation. This material, which generally includes the A and upper portion of the B horizons, is typically nonsaline, nonsodic, and permeable.

Many of the soil profiles showed a marked increase in soluble salts, exchangeable sodium and/or clay content below 12 to 18 inches (.30-.46m) in depth. Therefore, a significant percentage of the available subsurface materials in this study area were classified as fair or poor for placement below the primary plant rooting zone in reconstructed profiles.

A systematic evaluation was made of core samples from Bureau of Reclamation Drill Holes 78-101 and 102 and 79-103 through 115 in order to determine suitability of the materials for use as plant media. A complete set of laboratory data, including selected trace element determinations, provided the data base necessary to evaluate the core materials. Suitability criteria were applied to the laboratory data in order to place the bedrock materials into one of three classes: Suitable, Limited Suitability, or Unsuitable.

Overall, approximately 3 percent of the bedrock materials were rated Suitable for use as plant media, 7 percent were of Limited Suitability, and 90 percent were Unsuitable. Excessive exchangeable sodium was the major limiting factor for the samples classified as Limited Suitability or Unsuitable. Other limiting factors included high levels of soluble salts, high clay or sand percentages, high pH, and high concentrations of trace elements (surface samples from DH-79-104 and DH-79-107 had very high lead levels).

RECOMMENDATIONS FOR RECLAMATION

INTRODUCTION

Should surface mining occur in the Rattlesnake Butte Study Area, the coal mine operator will be required to restore all disturbed areas "in a timely manner to conditions that are capable of supporting the uses which they are capable of supporting before mining, or to higher or better uses . . ." (Chapter 38-14.1, Section 69-05.2-23-01. North Dakota Century Code).

Unless an alternative postmining land use is desired by the landowner(s) and approved by the North Dakota Public Service Commission, the main objective of reclamation will be to restore the mined land to a condition capable of supporting the uses that it supports today. These uses are rangeland, hayland, and cropland (small grains, corn, sunflowers).

STABILITY OF THE POSTMINING LANDSCAPE [1/]

The design of a stable postmining landscape in the Rattlesnake Butte Study Area will require the integration of several critical factors. These include: (1) a detailed knowledge of the distribution of overburden materials, with emphasis on the delineation of highly sodic spoils, (2) proper equipment selection, and (3) a consideration of seasonal factors. For reclamation to be successful, consideration must be given to the entire landscape, not merely the soil zone.

Three forms of landscape instability are common on reclaimed coal-mined areas in the Northern Great Plains. These are areawide settling, local collapse, and piping.

Areawide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This form of subsidence will probably be most pronounced during the first year following reclamation and will continue at a decreasing rate for a number of years. The two major factors influencing areawide settling are: (1) texture of the overburden, and (2) equipment used in spoil contouring operations.

A significant quantity of overburden in the Rattlesnake Butte Study Area consists of fine-textured material (shale). When disturbed, this material usually results in more blocky and, initially, more porous spoils than does coarse-textured overburden (sandstone). Therefore, a greater degree of areawide settling may be expected in this area as compared to an area where coarse-textured materials are predominant.

Equipment used in contouring operations is a critical factor influencing areawide settling. Settlement is significantly less in scraper-contoured areas than in dozer-contoured areas due to the fact that scrapers more

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1/ Groenewold, G.H. and Rehm, B.W., 1980 (modified)

effectively break down large overburden blocks and compact the spoil mass. Therefore, the degree of areawide settlement may be reduced by employing scrapers rather than dozers in spoil contouring operations.

Local large-scale collapse often develops soon after contouring is completed. Development typically ends within 1 year. This form of instability is predominant in precontouring valleys where large, frozen spoil blocks are concentrated by mid-winter dozer contouring. Thawing of these blocks results in local surface subsidence. To restrict the development of local collapse features, the use of scrapers rather than dozers should be considered for contouring operations during the winter months.

Piping appears to be a severe and long-term problem in some postmining landscapes. This form of instability usually begins soon after contouring ceases and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years.

Piping is apparently controlled by a combination of physical and chemical conditions in the spoils. All piping begins as a crack, either on the surface of exposed spoils or at the topsoil-spoil interface. In the latter case, the overlying topsoil collapses into the pipe and is carried away. Repeated topsoil application is usually unsuccesful in stopping the growth and development of piping. Cracking of spoils is restricted to areas of highly dispersive sodic materials. The cracks allow access for large volumes of surface runoff to flow into the subsurface of the spoils. However, surface cracking alone will not necessarily result in the development of piping. Piping will develop only if an avenue for water movement can result from fracturing within the mass of spoils due to settling between differentially compacted areas (i.e., scraper-contoured area adjacent to dozer-contoured area) or within areas of poorly compacted spoils (i.e. dozer contouring only).

Piping usually develops in nearly flat areas, where runoff is minimal and infiltration is maximized. Thus, the final surface slopes in reclaimed areas must also be recognized as controlling factors in the development of piping.

Given the proper conditions of slope, near-surface dispersive materials, and a permeable zone in the base of the spoils, piping may continue to develop and disrupt the restored landscape for many years. Selective placement of excessively sodic overburden encountered in this study area may prove to be the only effective means of controlling piping.

Because the postmining landscape in the Rattlesnake Butte Study Area will be unstable, structures should not be built unless they are specifically designed to absorb differential settlement. Also, reconstructed drainage channels will require periodic maintenance to ensure that ponded areas do not develop in areas of localized settling.

GRADING AND HANDLING OF SPOIL MATERIALS

Mine operators will be required by law to grade all disturbed areas "to the gentlest topography consistent with adjacent unmined landscape elements . . . ." All spoil shall be transported, backfilled, compacted (where advisable to insure stability or to prevent leaching), and graded to eliminate all highwalls, spoil piles, and depressions (Chapter 38-14.1, Section 69-05.2-21-01(2)(a), North Dakota Century Code).

Where possible, all final grading and preparation of graded land prior to the redistribution of topsoil should be conducted along the contour to minimize erosion and maximize landscape stability.

Present North Dakota law states: "Spoil materials that are found by the (Public Service) Commission to be excessively saline, sodic, or both, are considered to be toxic-forming materials and shall be covered with a minimum of 4 feet of nontoxic material, provided such material is available" (Chapter 38-14.1, Section 69-05.2-21-03(1), North Dakota Century Code). The results of laboratory tests performed on samples from 15 drill holes in the Rattlesnake Butte Study Area indicated that a significant number of the bedrock strata are excessively sodic. All samples from 5 of the 15 holes had high to very high levels of exchangeable sodium. In the remaining holes, most samples below 20 to 40 feet in depth were highly sodic. Based on this data, a 4-foot covering of nontoxic overburden over the entire study area may not be achievable. More detailed premining investigations will be necessary to accurately determine the location and quantity of available nonsodic overburden.

EROSION CONTROL

Reducing runoff and erosion and increasing the on-site conservation of moisture for vegetative establishment are feasible objectives for reclaimed land in the Rattlesnake Butte Study Area. The following procedure is recommended as a means toward achieving these objectives: (1) reduce the mean surface slope in the reclaimed area, (2) scarify the surface of the regraded spoils, (3) replace the subsoil/topsoil and prepare a seedbed, (4) conduct seeding and planting operations as soon as possible after topsoil redistribution, and (5) apply mulch to the newly seeded areas.

Reducing the mean slope in the reclaimed area will provide a more gently sloping landscape. A more level landscape will allow for an increase in infiltration and moisture retention and a decrease in runoff and sediment yield. The increase in moisture retention will be highly desirable for seedling establishment in the reclaimed area.

Prior to the redistribution of suitable plant growth material, the surface of the regraded spoils should be ripped or chiseled in order to eliminate slippage surfaces at the spoil-topsoil interface and provide a favorable

subsurface medium for air/water infiltration and root penetration. Ripping or chiseling should be conducted along the contour wherever possible to prevent runoff and ensure maximum stability.

Subsoil and topsoil are often compacted by heavy machinery during the redistribution process. These materials should be loosened by chiseling or other means prior to actual seedbed preparation (disking/harrowing). The loosened material will allow roots to readily penetrate its matrix and will also facilitate a higher rate of air/water infiltration. All tillage operations should be conducted along the contour to prevent excess runoff and substantial loss of the plant growth material.

Seeding and/or planting should be conducted as soon as possible after the topsoil has been spread and a seedbed has been prepared. The establishment of a permanent vegetative cover as quickly as possible will be the most effective method of controlling erosion in the reclaimed area. A temporary cover of small grains, grasses, or legumes may be required to protect the topsoil until such time as a permanent cover can be established.

Suitable mulch should be applied on all newly seeded areas to control erosion, conserve soil moisture, and enhance seed germination. The application of hay or straw mulch at a rate of about 2 tons/acre should be considered for the Rattlesnake Butte Study Area. To prevent substantial losses of the mulching material due to blowing, the hay or straw should be anchored (disked or crimped) to the soil surface.

REVEGETATION

Revegetation of surface-mined land in the Rattlesnake Butte Study Area will require: (1) removal, segregation, and redistribution of suitable plant growth material, (2) selection of adapted plant species, and (3) use of proper planting and seedbed preparation procedures.

Removal, Segregation, and Redistribution of Suitable Plant Growth Material

Prior to the actual mining operation, all suitable plant growth material should be removed and either redistributed immediately on regraded areas or segregated in separate stockpiles.

North Dakota regulations require that both topsoil and subsoil be salvaged for replacement as plant media (Chapter 38-14.1, Section 69-95.2-15-02(2), North Dakota Century Code). This is accomplished in a 2-lift process with the most desirable plant growth material ("topsoil") being removed in the first lift and the remaining suitable material ("subsoil") being salvaged in the second lift. Based on the results of the Land Suitability Classification included in this report, it appears that 6 to 12 inches (.15-.30m) of fair to good quality topsoiling material can be removed in the first lift from most soils in this study area (see Plates 38 through 46 following page 28). The quantity and quality of subsoil material to be salvaged in the second lift is highly variable in this study area (see Plates 47 through 55 following page 28).

If stockpiling of the suitable plant growth material is necessary, the stockpiles should be selectively placed on a stable area and protected from erosion, compaction and contaminants (toxic spoils). Establishment of a quick growing vegetative cover on the stockpiles is probably the most effective method of protection; however, other measures such as snow fences, mulches, or chemical binders may also be considered.

Before the suitable plant growth material is redistributed, the regraded land should be scarified (ripped) to eliminate slippage surfaces and enhance root penetration. The redistribution of subsoil and topsoil, respectively, should then proceed in a manner that achieves an approximate uniform thickness consistent with the postmining land use(s) and prevents excess compaction of the spoils and suitable plant growth material.

Finally, nutrients (fertilizer) and soil amendments should be added to the surface soil layer in the amounts determined by soil tests. All soil analyses should be performed by a qualified laboratory using procedures approved by the Public Service Commission (North Dakota).

Selection of Adapted Plants

To comply with established State regulations, the mine operator will be required to establish on all disturbed areas a "diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area . . ." (Chapter 38-14.1, Section 69-05.2-22-01, North Dakota Century Code). Introduced species may be substituted for native species only if appropriate field trials have demonstrated that the introduced species are of equal or superior utility for the approved postmining land use(s), or are necessary to achieve a quick, temporary, and stabilizing cover. The Public Service Commission must approve the use of introduced species.

Some important considerations in selecting revegetative species for the Rattlesnake Butte Study Area should include: drought resistance, salt and sodium tolerance, resistance to winterkill, palatability, and resistance to grazing pressure. Of equal importance is plant compatibility with soil type, slope, aspect, and drainage conditions.

Table 75 lists the plants and seeding rates which are suggested for native grassland plantings, tame grass plantings (areas to be returned to cropland after 3-4 years), and salt affected soil plantings.[2/]

Seedbed Preparation and Planting

Suitable plant growth material is often compacted by heavy machinery during the redistribution process. To provide a plant medium favorable for air and water infiltration, as well as root penetration, the topsoil/subsoil should be chiseled to a depth of 18 to 24 inches prior to seedbed preparation. Disking/harrowing should then be conducted until a suitable seedbed is achieved.

2/ From: Guidelines for Reclaiming Coal Mine Lands; North Dakota Public Service Commission, 1976.

Seeding of grasses and legumes with a press drill is usually the preferred technique; however, broadcasting is also a widely accepted method. Drilling is considered superior because the seed is covered to a proper depth, rate of seeding is controlled, seed distribution is uniform, and soil compaction can be accomplished with packer wheels attached to the drill. Broadcasting is considered less efficient because the seeds often perch on top of the soil where germination and establishment are difficult. Seed that is broadcast should always receive some form of mechanical treatment to give it suitable coverage, unless the bed is loose so that natural sloughing of soil will cover the seed.[4/]

Natural woodland complexes (woody draws) occur to a minor extent in this study area. These complexes should be avoided during the mining operation, if at all possible, as they are irreplaceable ecosystems and the majority of the prairie animal community is dependent on them. If disturbance of these complexes cannot be avoided, the trees and shrubs should be salvaged for transplanting in reconstructed drainages.

Seeding and planting operations should be conducted during the first normal period for favorable planting conditions following the redistribution of suitable plant growth material. In the Rattlesnake Butte Study Area, early spring or late fall planting of grasses and legumes appears most desirable. If spring planting is selected, the plants should be seeded between early March and late April in order that seedlings may emerge before the spring rains begin. If late fall planting is chosen, seeding should be conducted after mid-October to prevent germination.

POST-RECLAMATION MANAGEMENT

Responsibility of the Mine Operator

In North Dakota, the coal mine operator will be responsible for management of the reclaimed area for a minimum of 10 years. The success of revegetation will then be determined for each approved postmining land use according to the following:[5/]

1. For rangeland and hayland, the following requirement must be achieved for the last two consecutive years of the responsibility period:

   (a) "Ground cover and productivity . . . shall be equal to or greater than, with 90 percent statistical confidence for herbaceous vegetation and 80 percent statistical confidence for woody vegetation, the approved standards[6/], and

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4/ USDA - Forest Service, General Technical Report INT-64, 1979.

5/ The postmining land uses in the Rattlesnake Butte Study Area are assumed to be rangeland, hayland, and cropland (small grains, corn, sunflowers).

6/ Approved standard refers to an undisturbed "reference" area chosen for comparative purposes to determine success of revegetation on the reclaimed site.

NATIVE GRASSLAND PLANTINGS 3/

Species	Seeding Rate (lbs/acre)
Western wheatgrass	6
Pubescent wheatgrass*	1½
Little bluestem**	2
Sideoats grama	3
Green needlegrass	4
Alfalfa or	1
Sweetclover	½
Total	17-17½

* If seed not available, substitute slender wheatgrass.

** If seed not available, substitute prairie sandreed or switchgrass.

IMPROVED VARIETIES OF GRASS/LEGUME PLANTING FOR CROPLAND*

Species	Pasture or Hayland		Wildlife Planting
	Dry Site	Moist Site	
Crested wheatgrass	7	2	
Smooth bromegrass		5	
Pubescent wheatgrass**	3	3	
Intermediate wheatgrass			4
Tall wheatgrass			3
Alfalfa	1½	1½	3
Sweetclover	½	½	1
Total	12	12	11

* In pounds of seed per acre.

** If seed not available, substitute slender or intermediate wheatgrass.

SALT AFFECTED SOIL PLANTINGS

Species	Seeding Rate (lbs/acre)
Tall wheatgrass	4
Slender wheatgrass	3
Western wheatgrass	7
Sweetclover	2
Total	16

3/ Origin of native seed produced should be limited to North Dakota, South Dakota, eastern Montana, eastern Wyoming, and northern Nebraska.

(b) The diversity, seasonality, and permanence of the vegetation . . . , determined from the major species and groups, shall be equivalent to that of the approved standard" (Chapter 38-14.1, Section 69-05.2-22-07(3)(a), North Dakota Century Code).

2. For cropland, "crop production . . . shall be equal to or greater than, with 90 percent statistical confidence, that of the approved standard for the last two consecutive growing seasons of the responsibility period" (Chapter 38-14.1, Section 69-05.2-22-07(3)(b), North Dakota Century Code).

On lands reclaimed to rangeland, livestock grazing "shall be practiced for at least the last 4 years of the responsibility period at a capacity approximately equal to that for similar well managed lands" (Chapter 38-14.1, Section 69-05.2-22-06, North Dakota Century Code). The Public Service Commission, in consultation with the landowners(s), will determine when the revegetated area is ready for livestock grazing.

Responsibility of the Landowner

The landowners in the Rattlesnake Butte Study Area will resume responsibility for management of the reclaimed lands following termination of the mine operator's responsibility period. To ensure that the reclaimed land remains stable and productive, the landowners should implement proper range and soil/crop management practices.

On areas returned to rangeland, grazing should be limited to a capacity that the reclaimed land is capable of supporting. Overgrazing reclaimed lands will result in a reduced vegetative cover, accelerated erosion, and an overall decrease in productivity.

On lands returned to cropland, the main objective of the landowner in cultivating the land should be sustained profitable production. To aid in achieving this objective, soil/crop management practices including contour tillage, fertilization, crop rotation, weed and insect control, mulching, etc., should be utilized whenever possible.

SUMMARY OF RECLAMATION POTENTIAL

Based on the resource data presented in this report, the potential for restoring surface-mined land in the Rattlesnake Butte Study Area to a condition capable of supporting the present uses (rangeland, hayland, and cropland) appears good. The most critical factors directly influencing revegetation: (1) climate, and (2) availability of suitable plant growth material, both appear favorable in this study area.

The climatic regime in this area is conducive to the production of native range plants, small grains, and other adaptable crops. The moisture

available to plants from snowmelt and spring precipitation is usually adequate for germination and establishment. Although the growing season in this area is estimated at 122 days between mid- to late-May and mid- to late-September, native grasses and small grains will typically mature or become dormant by about mid-July when the available soil moisture is depleted.

Most soils in this study area should yield about 6 to 12 inches (.15-.30 m) of fair to good quality topsoil which is nonsaline, nonsodic, and moderately permeable. Given adequate moisture and a moderate amount of fertilization, this material should provide an excellent revegetative medium. Many of the soil profiles examined in the study area showed a marked increase in clay content, soluble salts, and/or exchangeable sodium in the subsurface horizons. Therefore, the quantity of suitable subsoil material available for replacement in reconstructed profiles may be limited. Permeable material that is moderately saline may be utilized as subsoil in deficient areas. This material should leach and reclaim readily under natural conditions if placed over spoils with good internal drainage characteristics. Sodic or clay-rich materials should be selectively placed below the root zone in reconstructed profiles.

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APPENDIX A

ENGLISH TO METRIC CONVERSIONS

ENGLISH TO METRIC (SI) CONVERSIONS

A dual system of measurements--English units and the International System (SI) of metric units--is given in this report. SI is a consistent system of units adopted by the Eleventh General Conference of Weights and Measures in 1960. Selected factors for converting English units to SI units are given below.

Multiply English Units	By	To Obtain SI Units
Inches	25.40	millimeters (mm)
	2.54	centimeters (cm)
	0.254	decimeters (dm)
	0.0254	meters (m)
Feet	0.3048	meters (m)
Square Feet	0.0929	square meters (m^2)
Miles	1.609	kilometers (km)
Pounds	453.60	grams (g)
Ton	0.9072	tonne (t)
Acres	0.4047	hectares (ha)
	0.004047	square kilometers (km^2)
Square miles	2.590	square kilometers (km^2)
Cubic inches	16.39	cubic centimeters (cm^3)
Gallons	.003785	cubic meters (m^3)
Acre-feet	.001233	cubic hectometers (hm^3)
	1233.00	cubic meters (m^3)
Feet per mile	0.1894	meters per kilometer (m/km)
Inches per hour	2.54	centimeters per hour (cm/h)
Feet per day	.3048	meters per day (m/d)
Pounds per square inch	70.32	grams per square centimeter (g/cm^2)
Atmospheres	1033.27	grams per square centimeter (g/cm^2)
Bars	1019.78	grams per square centimeter (g/cm^2)
Pounds per cubic foot	0.01602	grams per cubic centimeter (g/cm^3)
Pounds per acre	1.1206	kilograms per square hectometer (kg/hm^2)
Feet squared per day	0.0929	meters squared per day (m^2/d)
Cubic feet per second	0.02832	cubic meters per second (m^3/s)
Gallons per minute	0.06309	liters per second (l/s)
Cubic feet per second per square mile	0.01093	cubic meters per second per square kilometer [(m^3/s)/km^2]
Cubic feet per day per square foot	0.3048	cubic meters per day per square meter ($(m^3/d)/m^2$)
Pounds per square yard per hour	0.5426	kilograms per square meter per hour ($kg/m^2/h$)
Pounds per square foot per hour	4.8827	kilograms per square meter per hour ($kg/m^2/h$)
Btu per pound	0.556	kilogram calories per kilogram (kcal/kg)
Degree Fahrenheit	$Tc = \frac{Tf-32}{1.8}$	degrees Celsius (°C)

APPENDIX B
GEOLOGY

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: North Dakota
HOLE NO. DH78-101 — LOCATION: * — GROUND ELEV.: 2662± — DIP (ANGLE FROM HORIZ.): 90°
COORDS. N. ... E. ... — TOTAL DEPTH: 205.2' — BEARING: Vertical
BEGUN: 1/10/78 — FINISHED: 1/24/78 — DEPTH OF OVERBURDEN: -- —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: Not available * — LOGGED BY: R. Weisser — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Rig Damco 1250 truck mounted **Driller** Marvel Hermanson **Method** 0-2.1' continuous 8X drive sample. 2.1-30' continuous 8X drive rotation samples. Reamed hole with 3¾" dragbit at every 5' interval down to 30' (commencing at 5', etc.). 30-205.2' continuous HQ wireline core samples. **Drilling Conditions** Poor core recovery from 30 to 34.1'; bit plugged and part of sample washed away. Poor core recovery from 91.6 to 94.1'; part of sample washed away. Hard, well cemented sandstone from 104.5 to 107.7'. Driller noted core blocking off in inner core barrel from 122.8 to 124.4'; lost 0.6' of core sample. No drilling fluid return due to mud ring blocking off circulation from 144.6 to 154.7'. Poor core recovery from 168.3 to 205.2'; core sample washed away. **Caving Conditions** Driller was unable to get water level measurement probe past 63' (1/23/78). (Hole caved?) Driller was unable to get water level measurement probe past 74.2' (2/28/78). (Hole caved?)		100 96 41.5 100 95 100 94 99 98	#1 0 20 #2 20 40.9 #3 40.9 67 (minus) (lignite) (46.7-53.8) #4 67 80 #5 80 103.4 (minus) (lignite) (87.8-90.5)				2657.0 2621.1 2615.3 2608.2 2595.0 2582.0 2574.2 2571.5	5.0 40.9 46.7 53.8 67.0 87.8 90.5			SENTINEL BUTTE MEMBER---- PALEOCENE** 0 - 5.0' CLAYEY SANDSTONE: Light brown; oxidized; moist; uncemented and friable (crumbles with light digital pressure); fine grain; lightly ferruginous stained; calcareous; occasional, near horizontal (0-5°), laminated to thin shale interbeds; core lengths 1 to 5". 5.0 - 40.9' SHALE: Light brown 5.0-13.4' medium to dark gray 13.4-15.0', reddish brown 15.0-16.0', light grayish brown 16.0-30.0', light gray 30.0-40.9'; oxidized down to 30.0'; moist; firm, trims easily with knife; plastic; occasional white gypsum stringers to 1/4" thick at random orientation 5.0-20.0'; lightly ferruginous stained 5.0-13.4', moderately ferruginous stained 15.0-16.0'; near horizontal (0-5°), laminated bedding with occasional laminated siltstone interbeds; non-calcareous with lightly to moderately calcareous siltatone interbeds; core lengths 2 to 24". 13.4 - 15.0' - Carbonaceous zone; dark gray, brittle 14.5-15.0', numerous slickensides. 15.0 - 18.8' - Silty shale; numerous laminated siltstone interbeds, ferruginous streaks. 28.5 - 29.0' - Four (4) laminated lignite interbeds. 37.0 - 38.2' - Clayey sandstone; fine grain, uncemented and friable. 38.7 - 40.2' - Air slacks. 40.9 - 46.7' SILTY SANDSTONE: Light gray; moist; uncemented and friable (crumbles with moderate digital pressure); compact; fine grain; near horizontal (0-5°), laminated bedding; non-calcareous core lengths 1 to 18". 43.7 - 44.4' - Numerous, near horizontal (0-5°), laminated lignite interbeds. 46.4 - 46.7' - Lignitic shale; dark gray. 46.7 - 53.8' LIGNITE: Black; moist; hard; brittle and badly broken in upper portion. 53.8 - 67.0' SHALE: Light gray; moist; firm, trims easily with knife; near horizontal (0-5°), laminated bedding with numerous, laminated to thin siltstone interbeds; trace of laminated lignite	

EXPLANATION

CORE LOSS / CORE RECOVERY

*Location: 550' S. and 90' E. of W½ Corner Section 32, T. 140 N., R. 98 W.

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn; P = Packer, Cm = Cemented, Cs = Bottom of casing
Hole sealed — Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

** FT. UNION FORMATION

FEATURE: Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: N. Dak. — SHEET 1 OF 3 — HOLE NO. DH78-101

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE: Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: N. Dak.
HOLE NO. DH78-101 — LOCATION: * — GROUND ELEV.: 2662± — DIP (ANGLE FROM HORIZ.): 90°
COORDS. N. ... E. ... — TOTAL DEPTH: 205.2' — BEARING: Vertical
BEGUN: 1/10/78 — FINISHED: 1/24/78 — DEPTH OF OVERBURDEN: -- —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: Not available * — LOGGED BY: R. Weisser — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Water Return Depth — % Return 0-56.1' — 100 56.1-63.8' — 0 63.8-84.0' — 90 84.0-94.1' — 30 94.1-94.3' — 70 94.3-114.3' — 90-95 114.3-122.8' — 70 122.8-132.6' — 40 132.6-135.6' — 10 135.6-144.6' — 30 144.6-154.7' — 15 154.7-164.8' — 10 164.8-168.3' — 0 168.3-176.0' — 50-55 176.0-178.0' — 0 178.0-185.0' — 60 185.0-205.2' — 65-70 **Drilling Fluid** Depth — Fluid 0-63.8' — recirculated sterilized water 63.8-94.3' — reverse mud 94.3-144.6' — bentonite mud 144.6-205.2' — reverse mud **Casing Record** Casing Size — depth — Interval drilled -- -- — 0-2.1' 5" — 2.5' — 2.1-205.2' Pulled upon hole completion (2/28/78). **Progress Record** Date (78) — Depth — W.L. 1/10 — 0-25' — -- 1/11 — 25-30' — 17.2' 1/12 — 30-84' — 13.6' 1/17 — 84-114.3' — 64.1' 1/18 — 114.3-144.6' — 4.5* 1/19 — 144.6-164.8' — 78.5' 1/20 — 164.8-174.9' — 134.2' 1/23 — 174.9-185' — not available* 1/24 — 185-205.2' — 125.2' *Unable to get water level measurement probe past 63'.		100 100 94.1 100 97.1 99 100 0 100 0 100 0	#5 80 103.4 (minus) (lignite) (87.8-90.5) #6 103.4 122.9 #7 122.9 132.6 #8 149.9 165.3 #9 165.3 185 #10 185 205.2				2558.6 2539.1 2529.4 2512.1 2496.7	103.4 122.9 132.6 149.9 165.3			53.8 - 67.0' SHALE: (cont.) interbeds; slightly calcareous; core lengths 2 to 24". 55.5 - 57.5' - Air slacks; 45° joint at 56.0'. 59.5 - 60.7' - Near vertical lignite inclusiona. 65.1' - 70° slickensided joint. 67.0 - 80.0' SILTSTONE: Light gray; moist; firm, trims easily with knife; massive with numerous, near horizontal (0-5°), laminated to thin, medium gray shale interbeds; trace of laminated lignite interbeds; calcareous; core lengths 2 to 10". 80.0 - 87.8' SHALE: Medium gray; moist; firm, trims easily with knife; near horizontal (0-5°), laminated bedding with numerous, laminated, light gray siltatone interbeds; calcareous; core lengths 2 to 24". 86.1 - 86.2' - Hard, tan limestone (can be scratched with knife). 87.5 - 87.8' - Dark gray, carbonaceous. 87.8 - 90.5' LIGNITE: Black; moist; hard; brittle and broken. 90.5 - 103.4' SHALE: Medium gray; moist; firm, trims easily with knife; laminated bedding, near horizontal (0-5°) 90.5 - 95.1', low angle (5-10°) cross-bedding 95.1 - 103.4'; numerous laminated to thin siltstone interbeds; siltstone interbeds becoming sandy 95.1 - 103.4'; occasional lignite inclusions; calcareous; core lengths 3 to 12". 103.4 - 122.9' SANDSTONE: Light gray; moist; uncemented and friable (crumbles with light digital pressure) 103.4 - 104.5' and 107.7 - 122.9'; well cemented and hard (can be scratched with moderate knife pressure) 104.5 - 107.7'; fine grain; silty; bedding not readily discernible 103.4 - 104.5' and 107.7 - 122.9'; low angle (10-15°), laminated cross-bedding 104.5 - 107.7'; calcareous; core lengths 4" to 4'. 122.9 - 132.6' SHALE: Medium gray; moist; firm, trims easily with knife; near horizontal (0-5°), laminated bedding with occasional, laminated, light gray siltstone interbeds; fissile in places; trace of lignite inclusions; air slacks; 55° joint at 128.6'; non-calcareous with calcareous siltstone interbeds; core lengths 3" to 3.6'.	

EXPLANATION

CORE LOSS / CORE RECOVERY

*Location: 550' S. and 90' E. of W½ Corner Section 32, T. 140 N., R. 98 W.

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn; P = Packer, Cm = Cemented, Cs = Bottom of casing
Hole sealed — Approx. size of hole (X series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: N. Dak. — SHEET 2 OF 3 — HOLE NO. DH78-101

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE: Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: North Dakota
HOLE NO. DH78-101 — LOCATION: * — GROUND ELEV.: 2662± — DIP (ANGLE FROM HORIZ.): 90°
COORDS. N. ... E. ... — TOTAL DEPTH: 205.2' — BEARING: Vertical
BEGUN: 1/10/78 — FINISHED: 1/24/78 — DEPTH OF OVERBURDEN: -- —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: Not available * — LOGGED BY: R. Weisser — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Hole Completion Hole left open for water level measurements. Upon completion of water level measurements hole was backfilled with concrete to 3' from surface and sealed with a clay-bentonite mixture from 3' to original ground (2/28/78). **Water Levels** *Not available; unable to get water level measurement probe past 74.2' (2/28/78).		0	#10 185 205.2					2456.8	205.2 T.D.			132.6 - 149.9' LIGNITE: Black; moist; hard; brittle. 144.6 - 145.9' - Shale; dark gray. 149.9 - 165.3' SHALE: Medium gray; moist; firm, trims easily with knife; near horizontal (0-5°), laminated bedding with occasional, laminated, light gray siltatone interbeds; fissile in places; air slacks; trace of lignite inclusions; 60° joint at 150.4'; non-calcareous; core lengths 4" to 2.5'. 165.3 - 205.2' SANDSTONE: Poor core recovery (samples washed away); medium gray; wet; uncemented and friable (crumbles with light digital pressure); medium to predominantly fine grain; silty; bedding not readily discernible; numerous laminated sandy shale interbeds 165.3 - 166.8'; trace of laminated carbonaceous interbeds; slightly calcareous; core lengths of recovered core, loose to 14". Bottom of Hole - 205.2'	

EXPLANATION

CORE LOSS / CORE RECOVERY

*Location: 550' S. and 90' E. of W½ Corner Section 32, T. 140 N., R. 98 W.

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn; P = Packer, Cm = Cemented, Cs = Bottom of casing
Hole sealed — Approx. size of hole (X series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: N. Dak. — SHEET 3 OF 3 — HOLE NO. DH78-101

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD — NORTH DAKOTA

GEOLOGIC LOG OF DH 78-101

GEOLOGY R. WEISSER — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — FEBRUARY 1981 — SHEET 1 OF 1

1305-600-255

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH78-102 LOCATION * GROUND ELEV. 2632± DIP (ANGLE FROM HORIZ.) 90°
COORDS. N. E. TOTAL DEPTH 245.6' BEARING Vertical
BEGUN 1/26/78 FINISHED 2/24/78 DEPTH OF OVERBURDEN -- TOTAL DEPTH 245.6' BEARING Vertical
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 55.0' (2577±) 2/28/78 LOGGED BY R. Weisser LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Rig Damco 1250 truck mounted **Driller** Marvel Hermanson **Method** 0-1.5' continuous BX drive sample. 1.5-2.5' 4-7/8" drag-bit wash sample. 2.5-35' continuous BX drive rotation samples. Reamed hole with 3¾" dragbit at every 5' interval down to 35' (commencing at 5', etc.). 35-245.6' continuous HQ wireline core samples. **Drilling Conditions** No caving noted. Driller noted drill core compressed 0.1' from 10 to 15'. Hard limestone encountered from 33.5 to 33.7'; unable to recover core sample from 33.7 to 35'. Lost core sample from 61.3 to 63.8' and recovered 1.3' on second attempt. Lost bottom 2.1' of core sample from 63.8 to 71.9' interval; unable to recover. Poor core recovery from 174.9 to 245.6'; sample washed away. **Casing Record** Size: 5" — Casing depth: 2.5' — Interval drilled: 0-2.5' / 2.5-245.6' Pulled upon hole completion (2/28/78). **Progress Record** Date (78) — Depth — A.M. W.L. 1/26 — 0-35' — → 1/27 — 35-53.7' — 19.8' 1/31 — 53.7-82' — 42.8' 2/1 — 82-134.5' — 13.1' 2/2 — 134.5-144.6' — 4.0'	CASE	100										SENTINEL BUTTE MEMBER — PALEOCENE** 0 - 48.7' SHALE: Reddish-brown 0-35.0', medium gray 35.0-48.7'; oxidized down to 33.7'; moist; firm, trims easily with knife; ferruginous stained 0-33.7'; occasional white gypsum stringers to 1/8" thick along bedding planes and inclusions to 1/2" thick from 0 to 29.1' near horizontal (0-5°), laminated to thinly bedded with numerous laminated to thin siltstone interbeds; trace of lignite inclusions to 1/4" thick; air slacks 30.0-48.7'; non-calcareous; core recovered mostly in 0.5 to 1.5' segments, 2.1' maximum.
			#1									0 - 1.5' - Calcareous.
		100	0	25								7.5 - 9.1' - Sandy siltstone, light brown.
												24.2 - 27.8' - Sandy siltstone, light brown; silty sandstone from 26.8 to 27.3'.
		80										33.5 - 33.7' - Hard, ferruginous cemented.
			#2									33.7 - 35.0' - No core recovery.
		74	25	48.7								41.8' - 60° joint.
												41.9 - 45.3' - Plastic, fissile.
		92										46.0 - 48.7' - Bedding dips 5-10°.
								2583.3	48.7			48.7 - 60.8' LIGNITE: Black; moist; hard.
		94										57.3 - 58.2' - Lignitic shale; dark gray; moist; firm, trims easily with knife; plastic; fissile.
		100										60.8 - 64.6' SHALE: Medium gray; moist; firm, trims easily with knife; trace of lignite inclusions to 1/2" thick; near horizontal, laminated to thinly bedded
								2571.2	60.8			
		52										with numerous laminated to thin, light gray sandy siltstone interbeds, number of interbeds increase with depth; non-calcareous with slightly calcareous interbeds; core recovered mostly in 0.2 to 0.3' segments, 0.7' maximum.
								2567.4	64.6			
		74	#3									60.8 - 61.6' - Moderately plastic.
			60.8	83								64.0 - 64.2' - Silty sandstone, uncemented.
		100										64.6 - 83.0' SANDY SILTSTONE: Light to medium gray; moist; firm, trims easily with knife; massive with numerous laminated to thin shale and sandstone interbeds, low angle (5-15°) cross-bedding; calcareous; core recovered mostly in 0.4 to 1.3' segments, 3.6' maximum.
								2549.0	83.0			
		96	#4									
			83	98								
		97	(minus)					2541.9	90.1			
			(lignite)									
		100	(86.9-88.9)									

EXPLANATION

CORE LOSS / CORE RECOVERY

*Location: 140' S. and 700' W. of NE Corner Section 34, T. 140 N., R. 99 W.

Type of hole ..... D = Diamond, H = Hayestellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Hx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

** FT. UNION FORMATION

FEATURE Rattlesnake Butte Study Area Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 1 OF 3 HOLE NO. DH78-102

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH78-102 LOCATION * GROUND ELEV. 2632± DIP (ANGLE FROM HORIZ.) 90°
COORDS. N. E. TOTAL DEPTH 245.6' BEARING Vertical
BEGUN 1/26/78 FINISHED 2/24/78 DEPTH OF OVERBURDEN -- TOTAL DEPTH 245.6' BEARING Vertical
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 55.0' (2577±) 2/28/78 LOGGED BY R. Weisser LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Progress Record (cont.) Date (78) — Depth — A.M. W.L. 2/3 — -- — 38.5' 2/22 144.6-191.1' — 15.2' 2/23 191.1-215.3' — 19.7' 2/24 215.3-245.6' — 32.0' Note: Hole was not bailed at end of shift. **Water Return** Depth — % Return 0-48.5' — 100 48.5-53.7' — 0 53.7-139.5' — 100 139.5-144.6' — 5 144.6-245.6' — 100 **Drilling Fluid** Depth — Fluid 0-53.7' — recirculated sterilized water 53.7-245.6' — bentonite mud **Hole Completion** Flushed hole clean with 900 gallons sterilized water and bailed hole (2/27/78). Hole left open for water level measurements. Upon completion of water level measurements hole was backfilled with concrete from 245.6 to 3' and clay-bentonite mixture from 3' to original ground (2/28/78). **Water Levels** Date — Depth 2/27/78 — 66.2' 2/28/78 — 55.0'												83.0 - 90.1' SHALE: Light to medium gray color banded; moist; firm, trims easily with knife; near horizontal (0-5°), laminated to thinly bedded with numerous laminated to very thin, light gray sandy siltstone interbeds; calcareous; core recovered mostly in 0.3 to 0.8' segments, 1.3' maximum.
			#5									83.8 - 84.0' - Hard, medium gray limestone.
			98	112.8								86.4 - 86.9' - Lignitic shale, dark gray.
			#6									86.9 - 88.9' - Lignite, black; moist; hard.
			112.8	129.5								90.1 - 112.8' SANDY SILTSTONE: Light to medium gray; moist; firm, trims easily with knife; massive with numerous, near horizontal (0-5°), laminated to thin shale interbeds; trace of lignite inclusions to 1/2" thick from 100.0 to 102.0'; calcareous; core recovered mostly in 0.4 to 1.0' segments, 2.3' maximum.
								2519.2	112.8			
												94.2 - 94.4' - Sandstone, uncemented.
								2502.5	129.5			
												96.6 - 97.0' - Hard, tan limestone with pyrite crystal coating along vertical joint plane.
								2492.5	139.5			102.2 - 104.2' - Low angle (10-15°) cross-bedding.
			#7									104.2 - 106.4' - Silty sandstone, uncemented, bedding not readily discernible.
			129.5	159.9								106.8 - 108.0' - Shale, medium gray.
			minus lignite (131.7-133.2) and (139.5-150.9)									109.6 - 112.8' - Shale, medium gray.
								2481.1	150.9			
												112.8 - 129.5' SANDSTONE: Light gray; moist; uncemented and friable (crumbles with light to moderate digital pressure); fine grain; bedding not readily discernible; slightly calcareous; core recovered mostly in 0.4 to 1.5' segments, 2.3' maximum.
								2472.1	159.9			
								2467.7	164.3			121.8' - 1/2" lignite inclusion.
			#8									125.6 - 128.3' - Occasional, near horizontal (0-5°), laminated to thin shale interbeds.
			164.3	174.9								129.5 - 139.5' SHALE: Medium gray; moist, firm, trims easily with knife; low angle (5-10°) cross-bedding; laminated to thinly bedded with numerous laminated to thin sandy siltstone interbeds; trace of lignite inclusions to 1/8" thick; non-calcareous with calcareous sandy siltstone interbeds; core
			#9					2457.1	174.9			
			174.9	195								

EXPLANATION

CORE LOSS / CORE RECOVERY

*Location: 140' S. and 700' W. of NE Corner Section 34, T. 140 N., R. 99 W.

Type of hole ..... D = Diamond, H = Hayestellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Hx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 2 OF 3 HOLE NO. DH78-102

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH78-102 LOCATION * GROUND ELEV. 2632± DIP (ANGLE FROM HORIZ.) 90°
COORDS. N. E. TOTAL DEPTH 245.6' BEARING Vertical
BEGUN 1/26/78 FINISHED 2/24/78 DEPTH OF OVERBURDEN -- TOTAL DEPTH 245.6' BEARING Vertical
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 55.0' (2577±) 2/28/78 LOGGED BY R. Weisser LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		0										129.5 - 139.5' SHALE: (cont.) recovered mostly in 0.2 to 1.0' segments, 2.1' maximum.
		91	#10									131.7 - 133.2' - Lignite, black; moist; hard.
			195	217.7								133.3 - 133.8' - Sandy siltstone.
		84										135.2 - 135.5' - Silty sandstone, uncemented.
												136.3 - 136.7' - Silty sandstone, uncemented.
		81						2414.3	217.7			139.5 - 150.9' LIGNITE: Black; moist; hard.
												149.5 - 150.4' - Shale, medium gray, fissile, air slacks.
		100	#11									150.9 - 159.9' SANDY SHALE: Medium gray; moist; firm, trims easily with knife; near horizontal (0-5°), laminated to thinly bedded with occasional laminated sandstone interbeds; trace of pyrite crystals to 1/2" thick; non-calcareous; core recovered mostly in 0.2 to 0.8' segments, 1.3' maximum.
			217.7	245.6								152.5 - 158.5' - Silty sandstone, uncemented, numerous laminated lignite interbeds dipping 5-15°, non-calcareous.
		15						2386.4	245.6			159.9 - 164.3' LIGNITE: Black; moist; hard.
									T.D.			164.3 - 174.9' SILTY SANDSTONE: Medium gray; moist; uncemented and friable (crumbles with light to moderate digital pressure); fine grain; near horizontal (0-5°), laminated to thinly bedded with numerous laminated to thin shale interbeds and laminated lignite interbeds dipping 5-10°; calcareous; core recovered mostly in 0.4 to 1.3' segments, 2.5' maximum.
												174.9 - 217.7' SHALE: Medium gray; moist; firm, trims easily with knife; moderately plastic; near horizontal (0-5°), laminated to thinly bedded; air slacks; non-calcareous; core recovered mostly in 0.8 to 1.2' segments, 3.5' maximum.
												182.5 - 183.4' - Carbonaceous, dark gray.
												186.4 - 187.7' - Silty sandstone, uncemented.
												191.1 - 191.3' - Hard, tan limeatone.
												(continued at left)

174.9 - 217.7' SHALE: (cont.)
206.0 - 206.4' - Hard, tan limestone
208.6 - 209.6' - Occasional pelecypod and gastropod shell fragments.
212.5' - 70° slickensided joint.

217.7 - 245.6' SANDSTONE: Poor core recovery; medium gray; wet; uncemented and friable (crumbles with light digital preasure); medium to predominantly fine grain; silty; occasional laminated carbonaceous interbeds dipping 10-15° and numerous laminated to thin shale interbeds dipping 5-10° from 217.7 to 224.8', occasional shale interbeds from 224.8 to 245.6'; non-calcareous; core lengths of recovered core mostly in 0.2 to 0.8' segments, 1.2' maximum.
233.9 - 234.7' - Shale.

Bottom of Hole - 245.6'

EXPLANATION

CORE LOSS / CORE RECOVERY

*Location: 140' S. and 700' W. of NE Corner Section 34, T. 140 N., R. 99 W.

Type of hole ..... D = Diamond, H = Hayestellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Hx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 3 OF 3 HOLE NO. DH78-102

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD — NORTH DAKOTA

GEOLOGIC LOG OF DH 78-102

GEOLOGY L PARISH — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-256

GEOLOGIC LOG OF DRILL HOLE

Rattlesnake Butte Study Area — SHEET 1 OF 3

FEATURE Dickinson Coalfield — PROJECT EMRIA No. 22 — STATE North Dakota

HOLE NO. DH79-103 — LOCATION 750' N. & 50' E. of S.W. Corner Sec. 26, T. 141 N., R. 98 W. — GROUND ELEV. 2615'± — OIP (ANGLE FROM HORIZ.) Vertical

BEGUN 1-18-79 — FINISHED 1-25-79 — DEPTH OF OVERBURDEN 2.0' — TOTAL DEPTH 194.5' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE / LIMITED SUITABILITY / UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. **Driller** R.V. Shaw **Method** 8x casing drive samples 0-10'. Fishtail wash 10-11'. Hq wireline core 11-194.5'. Water used as drill fluid. Losses noted below: Depth — % Loss 11-44.5' 30-40 44.5-124.5' 20-30 124.5-194.5' 30-40 **Casing Record** None used. **Progress Record** Depth — Date 0-10' 1-18-79 10-11' 1-19-79 11-44.5' 1-22-79 44.5-124.5' 1-23-79 124.5-194.5' 1-24-79 Backfilled 1-25-79 **Hole Completion** Hole backfilled with concrete 1-25-79. **Water Levels** Taken before hole was completed. Depth — Date Dry to 11' 1-22-79 48' 1-24-79 69' 1-25-79	8x Hq	80 90 65 57 80 100 68 100 0 83 100 100	#1 0 #2 18.5 #3 40 #4 57.5 #5 90	17 40 55 79 105		2613 2605 2601.5 2598 2596.5 2575 2560 2557.5 2547.5 2539 2536 2525 2522.5	2 10 13.5 17 18.5 40 55 57.5 67.5 76 79 92.5			SENTINEL BUTTE MEMBER----PALEOCENE** 0-10.0' SANDSTONE and SHALE: highly weathered; light grayish brown with rusty areas; moist; soft; loose to crumbly; appears lensey with alternating layers of fine grained, uncemented sandstone and sandy shale; weak to moderate HCl reaction; bedding nearly horizontal; core lengths to 1". 0-2.0' TOPSOIL - dark brown. 10.0-13.5' CLAYEY SANDSTONE: grayish brown with some rust stains; moist; uncemented; soft; cuts easily with knife; fine grained; weathered; about half clay; no HCl reaction; bedding nearly horizontal; core lengths to 4". 12.0-12.8' Three joints - 2 nearly vertical and 1 dipping about 45°; all rust stained. 13.5-17.0' SHALE: grayish brown; moist; soft; cuts easily with knife; weathered; plastic; no HCl reaction; bedding not discernible; core lengths to 6". 17.0-18.5' ? COAL: poor recovery; most washed away; weathered to almost a black powder. 18.5-40.0' SHALE: grayish brown grading to gray below 34'; moist; soft; cuts easily with knife; no HCl reaction; bedding nearly horizontal; core lengths to 24". 20.0' Slickensides dipping 60°. 24.5-24.8 Carbonaceous. 25.0' Slickensides dipping 45°. 27.0' Joint - possibly slickensided; rust coated and lined with gypsum crystals; dips 80°. 28.5' Joint - rust stained; dips 70°. 35.0' Joint - dips 45°. 40.0-55.0' SANDY SHALE: medium gray; moist; soft; cuts easily with knife; scattered sandy zones and clayey sandstone lenses ranging to 18" thick; no HCl reaction; bedding nearly horizontal; core lengths to 12". 55.0-57.5' CALCAREOUS SANDSTONE: light gray; dry; cemented; hard; fine grained; micaceous; strong HCl reaction; bedding nearly horizontal; core lengths to 18". 57.5-67.5' CLAYEY SANDSTONE: poor recovery; top part washed away; medium gray; moist; uncemented; soft; cuts easily with knife; fine grained; no HCl reaction; bedding not discernible; core lengths to 12". 67.5-76.0' SHALE: medium gray; moist; soft; cuts easily with knife; plastic; no HCl reaction; bedding nearly horizontal; core lengths to 30".

** FT. UNION FORMATION

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... O = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) .. Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area ..... PROJECT EMRIA No. 22 ..... STATE N. Dak. ... SHEET 1 OF 3 .. HOLE NO. DH79-103
Dickinson Coalfield

GEOLOGIC LOG OF DRILL HOLE

Rattlesnake Butte Study Area — SHEET 2 OF 3

FEATURE Dickinson Coalfield — PROJECT EMRIA No. 22 — STATE North Dakota

HOLE NO. DH79-103 — LOCATION 750' N. & 50' E. of S.W. Corner Sec. 26, T. 141 N., R. 98 W. — GROUND ELEV. 2615'± — OIP (ANGLE FROM HORIZ.) Vertical

BEGUN 1-18-79 — FINISHED 1-25-79 — DEPTH OF OVERBURDEN 2.0' — TOTAL DEPTH 194.5' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE / LIMITED SUITABILITY / UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		40 110 7 120 15 130 98 140 100 150 100 89 160 75 170 72 180 100 190 95	#6 105 133.7 #7 134.2 140.2 #8 140.2 154 #9 154 174.7 #10 176.7 194.5			2510 2481.3 2480.8 2479.7 2474.8 2461 2458.5 2445.5 2440.3 2438.3 2434 2420.5	105 133.7 134.2 135.3 140.2 154 156.5 169.5 174.7 176.7 181 194.5			76.0-79.0' CARBONACEOUS SHALE: dark gray to black; moist; plastic; air slakes; numerous pyrite nodules in bottom foot; no HCl reaction; bedding nearly horizontal; core lengths to 6". 77.5' Joint - dips 60°. 79.0-90.0' COAL: brownish black; hard; brittle. 90.0-92.5' CARBONACEOUS SHALE: black; moist; firm; reasonably hard to trim with knife; plastic; air slakes; numerous low angle slickensides; no HCl reaction; bedding not discernible; core lengths to 18". 92.5-105.0' SANDY SHALE: light gray; moist; soft; cuts easily with knife; some crossbedding in sandy zones; no HCl reaction; bedding nearly horizontal; core lengths to 12". 105.0-133.7' SANDSTONE: light gray; moist; uncemented; very soft and crumbly; fine grained; below 126' it contains very numerous carbonaceous or coaly stringers and layers of fossilized plant material, most lie at angles between 20° and horizontal; no HCl reaction; bedding not discernible; core lengths to 18". 133.7-134.2' COAL: black; soft; earthy; broken. 134.2-135.3' CARBONACEOUS SHALE: black; moist; firm; reasonably hard to trim with knife; plastic; air slakes; no HCl reaction; bedding not discernible; core lengths to 4". 135.3-140.2' BENTONITIC SHALE: light greenish gray; damp; firm; hard to trim with knife; plastic; feels soapy; weak HCl reaction; bedding not discernible; core lengths to 24". 140.2-154.0' SHALE: medium to dark gray; damp; firm; fairly hard to trim with knife; no HCl reaction; plastic; some air slaking; bedding nearly horizontal; core lengths to 18". 146.0-146.8' Carbonaceous zone. 148.0-150.0' Carbonaceous zone. 151.0' Joint dipping 60°. 154.0-156.5' CLAYEY SANDSTONE: medium gray; moist; uncemented; crumbles easily; fine grained; no HCl reaction; bedding nearly horizontal; core lengths to 24". 156.5-169.5' SHALE: medium gray; moist; soft; cuts fairly easily with knife; no HCl reaction; bedding nearly horizontal; core lengths to 24".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... O = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) .. Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area ..... PROJECT EMRIA No. 22 ..... STATE N. Dak. ... SHEET 2 OF 3 .. HOLE NO. DH79-103
Dickinson Coalfield

GEOLOGIC LOG OF DRILL HOLE

Rattlesnake Butte Study Area — SHEET 3 OF 3

FEATURE Dickinson Coalfield — PROJECT EMRIA No. 22 — STATE North Dakota

HOLE NO. DH79-103 — LOCATION 750' N. & 50' E. of S.W. Corner Sec. 26, T. 141 N., R. 98 W. — GROUND ELEV. 2615'± — OIP (ANGLE FROM HORIZ.) Vertical

BEGUN 1-18-79 — FINISHED 1-25-79 — DEPTH OF OVERBURDEN 2.0' — TOTAL DEPTH 194.5' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE / LIMITED SUITABILITY / UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		10 20 30 40 50 60 70 80 90								169.5-174.7' CLAYEY SANDSTONE: medium gray; moist; uncemented; crumbles easily; scattered shaley zones; fine grained; no HCl reaction; bedding nearly horizontal; core lengths to 24". 172.3-172.6' Numerous thin coal laminae. 173.1-173.3' Numerous thin coal laminae. 174.4-174.7' Carbonaceous, shaley zone. 174.7-176.7' COAL: brownish black; hard; brittle. 176.7-181.0' SHALE: medium gray; damp; firm; reasonably hard to trim with knife; plastic; air slakes; no HCl reaction; bedding nearly horizontal; core lengths to 24". 181.0-194.5' SANDSTONE: medium gray; moist; uncemented; soft; crumbles easily; fine grained; no HCl reaction; bedding nearly horizontal; core lengths to 12". 188.0-191.0' Calcareous; light gray; dry; very hard; strong HCl reaction.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... O = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) .. Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area ..... PROJECT EMRIA No. 22 .. STATE N. Dak. ... SHEET 3 OF 3 .. HOLE NO. DH79-103
Dickinson Coalfield

METERS 0 1 2 3 4 5 6 7 8 9 — FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD — NORTH DAKOTA

GEOLOGIC LOG OF DH 79-103

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-257

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

Rattlesnake Butte Study Area

FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota

HOLE NO. DH79-104 LOCATION 700' E. & 50' N. of S.W. Corner Sec. 32, T. 141 N., R. 98 W. GROUND ELEV. 2695' ± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 1-30-79 FINISHED 2-2-79 DEPTH OF OVERBURDEN 2.0' TOTAL DEPTH 120.0' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. **Driller** R.V. Shaw **Method** Bx casing drive samples 0-10', 4½" fishtail wash 10-11'. Hq wire-line core 11-120'. Water used as drill fluid. Losses noted below: Depth — XLoss 0-100 — 0 100-120 — 30 **Casing Record** Set 5" to 10' 1-30-79. Pulled on completion. **Progress Record** Depth — Date 0-34.5' — 1-30-79 34.5-120' — 2-1-79 Backfilled 2-2-79 **Hole Completion** Hole backfilled with concrete 2-2-79. **Water Levels** Taken before hole was completed. Depth — Date Dry to 30' — 2-1-79 68' — 2-2-79	Bx	80						2693	2			SENTINEL BUTTE MEMBER---PALEOCENE** 0-33.5' SANDSTONE: highly weathered; brown; moist; uncemented; loose; fine grained; poor recovery-most washed away; weak to no HCl reaction; bedding not discernible. 0-2.0' TOPSOIL- dark brown, clayey sand. 33.5-37.5' CARBONACEOUS SHALE: dark gray to black; moist; soft; cuts easily with knife; plastic; bedding nearly horizontal; no HCl reaction; core lengths to 15". 37.5-42.2' SILTY SHALE: light gray; moist; soft; cuts easily with knife; feels silty; no HCl reaction; bedding nearly horizontal; core lengths to 20". 42.2-43.0' COAL: black; moist; soft; earthy; contains numerous slickensides; badly broken. 43.0-54.5' SHALE: medium gray; moist; soft; cuts easily with knife; plastic; bedding not discernible; no HCl reaction; core lengths to 24". 43.0-44.0' Carbonsceous; black. 44.5' Joint dipping 60°. 54.5-64.5' SANDY SHALE: medium gray; moist; soft; cuts easily with knife; composed of about ¼ fine sand; some crossbedding; no HCl reaction; core lengths to 24". 64.5-66.0' SANDSTONE: medium gray; moist; uncemented; soft; crumbles very easily; fine grained; no HCl reaction; bedding not discernible; core lengths to 15". 66.0-68.5' SANDY LIMESTONE: light gray; dry; hard; strong HCl reaction; bedding not discernible; core lengths to 10". 68.5-72.0' SANDSTONE: medium gray; moist; uncemented; crumblea eesily; fine grained; no HCl reaction; bedding not discernible; core lengths to 12". 72.0-84.0' SHALE: dark gray; moist; soft; cuts easily with knife; plastic; scattered sandy zones near top; no HCl reaction; bedding nearly horizontal; core lengths to 30". 84.0-85.3' COAL: black; moist; soft; broken; earthy; numerous slickensides, especially near top. 85.3-94.5' SHALE: dark grsy; moist; soft; cuts easily with knife; plastic; no HCl reaction; bedding not discernible; core lengths to 36". 94.5-103.0' COAL: black; moist; soft; broken; numerous slickensides.
		0										
		0										
	Hq	0	#1 0	33.5								
		0										
		20										
		100	#2 33.5	42.2				2661.5	33.5			
								2657.5	37.5			
								2652.8	42.2			
								2652	43			
		61	#3 43	54.5				2640.5	54.5			
		80	#4 54.5	66				2630.5	64.5			
								2629	66			
		100						2626.5	68.5			
		100	#5 68.5	84				2623	72			
		100										
								2611	84			
		90	#6 85.3	94.5				2609.7	85.3			
								2600.5	94.5			
		100										

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

** FT. UNION FORMATION

FEATURE Rattlesnake Butte Study Area Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 1 OF 2 HOLE NO. DH79-104

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

Rattlesnake Butte Study Area

FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota

HOLE NO. DH79-104 LOCATION 700' E. & 50' N. of S.W. Corner Sec. 32, T. 141 N., R. 98 W. GROUND ELEV. 2695' ± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 1-30-79 FINISHED 2-2-79 DEPTH OF OVERBURDEN 2.0' TOTAL DEPTH 120.0' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100						2592	103			103.0-111.1' SHALE: light gray; moist; soft; cuts easily with knife; plastic; no HCl reaction; bedding not discernible; core lengths to 30". 103.0-104.0' Carbonaceous; dark gray; slickensides dipping 60°. 104.0-107.0' Numerous slickensided core breaks dipping 60°. 109.0-111.1' Carbonaceous; dark gray; scattered coaly zones. 111.1-113.3' COAL: black; moist; soft; broken. 113.3-120.0' SHALE: gray; moist; soft; cuts easily with knife; plastic; no HCl reaction; bedding not discernible; core lengths to 6".
		100	#7 103	111.1				2583.9	111.1			
								2581.7	113.3			
		59	#8 113.3	120				2575				

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 2 OF 2 HOLE NO. DH79-104

METERS 0 1 2 3 4 5 6 7 8 9

FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD — NORTH DAKOTA

GEOLOGIC LOG OF DH 79-104

GEOLOGY L. PARISH FIELD APPROVAL

DRAWN TECH. APPROVAL

CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-258

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-105 LOCATION 50' N. & 800' W. of S.E. Corner Sec. 24, T. 140 N., R. 99 W. GROUND ELEV. 2565'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 2-5-79 FINISHED 2-22-79 DEPTH OF OVERBURDEN 2.0' TOTAL DEPTH 244.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. **Driller** R.V. Shaw **Method** Bx casing drive samples 0-10'. Fishtail wash 10-11'. Hq wireline core 11-244.5'. Water and Revert used as drill fluid. No water losses noted. **Casing Record** None used. **Progress Record** Depth Date 0-101.5' 2-5-79 101.5-157.5' 2-6-79 157.5-183.0' 2-14-79 183.0-224.5' 2-21-79 224.5-244.5' 2-22-79 **Hole Completion** Hole backfilled with concrete. 2-22-79. **Water Levels** Taken before hole was completed. Depth Date 27.5' 2-6-79 46.5' 2-14-79 43.0' 2-21-79 47.2' 2-22-79	Bx Wash Hq	80 60 0 80 100 74 100 100 87 100 48 90 95 77 95	#1 0 #2 20.5 #3 30.7 #4 49.2 #5 58.1 #6 67.8 #7 77.0	20.5 29.5 39.7 57.1 65.1 77.0 95.0				2563 2544.5 2541.5 2535.5 2534.3 2525.3 2515.8 2507.9 2506.9 2499.9 2497.2 2488	2 20.5 23.5 29.5 30.7 39.7 49.2 57.1 58.1 65.1 67.8 77			SENTINEL BUTTE MEMBER----PALEOCENE** 0-20.5' SILTY SHALE: tan to brown; damp; weathered; oxidized; crumbled 0-10'; cuts easily with knife 10-20.5'; bedding not discernible; strong HCl reaction 0-10'; no HCl reaction below 10'; core lengths to 5". 0-2.0' TOPSOIL - dark brown. 20.5-23.5' SANDY SHALE: brownish gray; moist; oxidized; trims easily with knife; numerous thin sandstone laminae; bedding nearly horizontal; no HCl reaction; core lengths to 18". 23.5-29.5' SHALE: dark gray; damp; firm; trims easily with knife; plastic; air slakes; bedding nearly horizontal; no HCl reaction; core lengths to 12". 29.5-30.7' COAL: brownish black; damp; brittle. 30.7-39.7' SHALE: medium gray; damp; firm; trims easily with knife; plastic; air slakes; bedding nearly horizontal; no HCl reaction; core lengths to 20". 39.7-49.2' COAL: brownish black; damp; earthy; contains numerous light gray shale layers ½ to 2" thick; driller estimates that 25% of unit is shale. 49.2-57.1' CLAYEY SANDSTONE: light gray; moist; uncemented; cuts easily with knife; fine grained; unit consists of finely laminated layers of sand and clay; bedding nearly horizontal; no HCl reaction; core lengths to 20". 57.1-58.1' COAL: brownish black; damp; brittle. 58.1-65.1' SANDY SHALE: poor recovery; medium gray; damp; firm; trims easily with knife; bedding nearly horizontal; no HCl reaction; core lengths to 15". 65.1-67.8' COAL: brownish black; damp; brittle; woody. 67.8-77.0' SANDY SHALE: medium gray; damp; trims fairly easily with knife; numerous thin, fine grained sandstone layers; bedding nearly horizontal; no HCl reaction; core lengths to 24". 77.0-144.6' SANDSTONE: highly variable; light to medium gray; damp to wet; varies from uncemented and loose to cemented and very hard; fine grained; some clayey laminae near top of unit; bedding nearly horizontal with some crossbedding; no HCl reaction for most of unit; strong HCl reaction in calcareous cemented zones; core lengths to 24". Light gray, calcareous cemented, hard zones occur at the following

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) ..... Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) ..... Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8", ** FT. UNION FORMATION
Outside dia. of casing (X-series) ..... Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) ..... Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 1 OF 3 HOLE NO DH79-105

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-105 LOCATION 50' N. & 800' W. of S.E. Corner Sec. 24, T. 140 N., R. 99 W. GROUND ELEV. 2565'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 2-5-79 FINISHED 2-22-79 DEPTH OF OVERBUROEN 2.0' TOTAL DEPTH 244.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		92 #8 95.0 115.0 60 20 #9 115.0 135.0 80 100 #10 135.0 144.6 20 100 #11 144.9 159.4 93 #12 159.4 172.0 75 #13 172.4 180.5 100 #14 180.5 192.5 100 100						2420.4 2420.1 2408 2405.6 2383 2392.6 2387 2384.5 2379 2372.5	144.6 144.9 157 159.4 172 172.4 178 180.5 186 192.5			intervals: 102.0-103.2'; 105.0-107.0' and 111.5-113.0'. 144.6-144.9' COAL: brownish black; damp; brittle. 144.9-157.0' SHALE: medium gray; damp; trims easily with knife; scattered sandstone lenses near bottom; bedding nearly horizontal; no HCl reaction; core lengths to 14". 157.0-159.4' SANDSTONE: light gray; moist; uncemented; crumbles easily; fine grained; bedding nearly horizontal; no HCl reaction; core lengths to 10". 159.4-172.0' SHALE: medium to dark gray; damp; trims easily with knife; plastic; air slakes; scattered sandy zones; carbonaceous 163.8-164.3' and 171.5-172.0'; bedding nearly horizontal; no HCl reaction; core lengths to 24". 162.5' Joint dipping 45°. 172.0-172.4' COAL: brownish black; damp; brittle. 172.4-178.0' SHALE: medium to dark gray with some greenish gray; moist; trims easily with knife; nearly whole unit has a crushed appearance and is loaded with slickensides; carbonaceous near top; plastic; air slakes; bedding not discernible; no HCl reaction; core lengths to 24". 178.0-180.5' SANDSTONE: medium gray; moist; uncemented; crumbles easily; fine grained; bedding not discernible; pyrite nodules at top of unit; no HCl reaction; core lengths to 20". 180.5-186.0' SHALE: dark gray; damp; trims easily with knife; plastic; air slakes; bedding nearly horizontal; no HCl reaction; core lengths to 20". 181.8' Joint dipping 20°. 186.0-192.5' SANDY SHALE: light gray; damp; trims easily with knife; numerous lenses of sandstone; bedding nearly horizontal; moderate HCl reaction; core lengths to 36". 192.5-223.0' SHALE: medium to dark gray; damp; trims with some difficulty; plastic; air slakes; widely scattered sandy zones; no HCl reaction except in sandy zones-moderate there; bedding nearly horizontal; core lengths to 36". 196.0-196.8' LIMESTONE - light gray; dry; hard. 221.0-223.0' Carbonaceous; nearly black. 223.0-231.3' COAL: black; moist; soft; broken.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) ..... Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) ..... Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) ..... Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) ..... Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 2 OF 3 HOLE NO DH79-105

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-105 LOCATION 50' N. & 800' W. of S.E. Corner Sec. 24, T. 140 N., R. 99 W. GROUND ELEV. 2565'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 2-5-79 FINISHED 2-22-79 DEPTH OF OVERBURDEN 2.0' TOTAL DEPTH 244.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100 #15 192.5 223.0 92 100 #16 231.3 244.5 95						2342 2333.7 2320.5	223 231.3 244.5			231.3-244.5' SANDY SHALE: light gray; moist; trims easily with Knife; extremely sandy; laminated; bedding nearly horizontal; weak to moderate HCl reaction; core lengths to 20."

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) ..... Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) ..... Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) ..... Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) ..... Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 3 OF 3 HOLE NO DH79-105

METERS / FEET

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD – NORTH DAKOTA

GEOLOGIC LOG OF DH 79-105

GEOLOGY L. PARISH FIELD APPROVAL
DRAWN TECH. APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY 1981 SHEET 1 OF 1

1305-600-259

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Rattlesnake Butte Study Area — PROJECT: EMRIA No. 22 — STATE: North Dakota
HOLE NO.: DH79-106 — LOCATION: 1500' S. & 65' W. of N.E. Corner Sec. 26, T. 140 N., R. 98 W. — GROUND ELEV.: 2620'± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 2-26-79 — FINISHED: 3-1-79 — DEPTH OF OVERBURDEN: 2.0' — TOTAL DEPTH: 224.5' — BEARING:
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes — LOGGED BY: Parish — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. Driller R.V. Shaw Method Bx casing drive samples 0-10'. Fishtail wash 10-11' Hq wireline core 11-224.5'. Water and Revert used as drill fluid. Water losses noted below. Depth / % Loss 0-21' / 0 21-113.5' / 50-70 113.5-224.5' / 70-80 Casing Record None used. Progress Record Depth / Date 0-21' / 2-26-79 21-113.5' / 2-27-79 113.5-224.5' / 2-28-79 Backfilled 3-1-79 Hole Completion Hole backfilled with concrete 3-1-79. Water Levels Taken before hole was completed. Depth / Date Dry to 18' / 2-27-79 69.5' / 2-28-79 69.7' / 3-1-79	Bx Hq	70 30 #1 0 22 35 91 85 #2 23.5 44.5 95 70 #3 44.5 63 Minus Coal 100 100 #4 63 80 100 100 #5 80 96.5 100						2618 2598 596.5 2575.5 2565.7 2565.5 2557 2523.5	2 22 23.5 44.5 54.3 54.5 63 96.5			SENTINEL BUTTE MEMBER----PALEOCENE** 0-22.0' SILTY SHALE: dark gray to brown; damp; soft and crumbly; weathered; oxidized; moderate to strong HCl reaction; bedding nearly horizontal; core lengths to 12". 0-2.0' TOPSOIL - dark grayish brown; organic. 2.5-3.5' Scattered caliche. 22.0-23.5' LIMESTONE: light gray; dry; hard; bedding nearly horizontal; core lengths to 10". 23.5-44.5' SILTY SHALE: light brown; damp; cuts easily with knife; oxidized; bedding nearly horizontal; weak HCl reaction; core lengths to 18". 44.5-63.0' SHALE: medium to dark gray; damp; trims with some difficulty; plastic; air slakes; slightly carbonaceous, especially near 54'; bedding nearly horizontal; weak HCl reaction; core lengths to 18". 54.3-54.5' COAL - black; brittle. 63.0-96.5' SANDY SHALE: medium gray; damp; trims with some difficulty; scattered laminated sandy zones; bedding nearly horizontal; a few carbonaceous zones below 85'; no HCl reaction core lengths to 36". 96.5-108.2' COAL: brownish black; wet; soft; woody; broken. 108.2-118.0' SHALE: medium to dark gray moist; cuts fairly easily with knife; a few scattered sandy zones; bedding nearly horizontal; core lengths to 20". 112.5' Joint dipping 45°. 118.0-123.5' CLAYEY SANDSTONE: light to medium gray; damp; uncemented; cuts easily with knife; fine grained; some crossbedding but most bedding nearly horizontal; no HCl reaction; core lengths to 20". 123.5-129.5' SHALE: medium gray; damp; trims easily with knife; bedding nearly horizontal; no HCl reaction; core lengths to 20". 129.5-129.7' COAL: black; damp; hard; brittle. 129.7-146.7' SANDY SILTSTONE: light gray, with a greenish tint near the top; moist; soft; cuts easily with knife; bedding nearly horizontal; no HCl reaction; core lengths to 12". 146.7-149.7' SANDY LIMESTONE: light gray; dry; hard; some crossbedding; very poor plant fossils; pyrite along a near vertical joint at 148.7'; core lengths to 8".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

** FT. UNION FORMATION

FEATURE: Rattlesnake Butte Study Area — PROJECT: EMRIA No. 22 — STATE: N. Dak. — SHEET 1 OF 3 — HOLE NO. DH79-106

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE: Rattlesnake Butte Study Area — PROJECT: EMRIA No. 22 — STATE: North Dakota
HOLE NO.: DH79-106 — LOCATION: 1500' S. & 65' W. of N.E. Corner Sec. 26, T. 140 N., R. 98 W. — GROUND ELEV.: 2620'± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 2-26-79 — FINISHED: 3-1-79 — DEPTH OF OVERBURDEN: 2.0' — TOTAL DEPTH: 224.5' — BEARING:
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes — LOGGED BY: Parish — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100 100 #6 108.2 118 100 #7 118 129.5 100 100 #8 129.7 146.7 100 27 #9 149.7 169 Sand Washed Away Sand Washed Away #10 169 198.7 100 100 100						2511.8 2502 2496.5 2490.5 2490.3 2473.3 2470.3 2421.3	108.2 118 123.5 129.5 129.7 146.7 149.7 198.7			149.7-198.7' SANDSTONE: light gray; moist; uncemented; soft; crumblea easily; fine grained; weak HCl reaction; bedding nearly horizontal; core lengths to 40". 198.7-208.2' COAL: brownish black; wet; soft; brittle; woody; broken. 208.2-224.5' SANDY SHALE: medium to dark gray; moist; trims with difficulty; no HCl reaction; bedding nearly horizontal; core lengths to 14". 209.2-210.0' COAL - laminated with shale. 224.0-224.3' COAL - brownish black; slickensided along bottom.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Rattlesnake Butte Study Area — PROJECT: EMRIA No. 22 — STATE: N. Dak. — SHEET 2 OF 3 — HOLE NO. DH79-106

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE: Rattlesnake Butte Study Area — PROJECT: EMRIA No. 22 — STATE: North Dakota
HOLE NO.: DH79-106 — LOCATION: 1500' S. & 65' W. of N.E. Corner Sec. 26, T. 140 N., R. 98 W. — GROUND ELEV.: 2620'± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 2-26-79 — FINISHED: 3-1-79 — DEPTH OF OVERBURDEN: 2.0' — TOTAL DEPTH: 224.5' — BEARING:
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes — LOGGED BY: Parish — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100 100 #11 208.2 224.5 Minus Coal 70						2411.8 2410.8 2410 2396 2395.7 2395.5	208.2 209.2 210 224 224.3 224.5			

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Rattlesnake Butte Study Area — PROJECT: EMRIA No. 22 — STATE: N. Dak. — SHEET 3 OF 3 — HOLE NO. DH79-106

METERS 0 1 2 3 4 5 6 7 8 9 — FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 79-106

GEOLOGY: L. PARISH — FIELD APPROVAL:
DRAWN: — TECH. APPROVAL:
CHECKED: — APPROVED:

BILLINGS, MONTANA — FEBRUARY 1981 — SHEET 1 OF 1 — 1305-600-260

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Rattlesnake Butte Study Area / Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: North Dakota

HOLE NO. DH79-107 — LOCATION: 2550' E. & 60' S. of N.W. Corner Sec. 14, T. 140 N., R. 98 W. — GROUND ELEV.: 2670'± — OIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 3-6-79 — FINISHED: 3-8-79 — DEPTH OF OVERBURDEN: 2.0' — TOTAL DEPTH: 213.5' — BEARING:

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes — LOGGED BY: Parish — LOG REVIEWED BY:

HOLES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. **Driller** R.V. Shaw **Method** 8x casing drive samples 0-10'. Fishtail wash 10-11'. Hq wireline core 11-213.5'. Water and Revert used as drill fluid. Water losses noted below. Depth XLoss 0-74.5' 10-20 74.5-173.5' 0 173.5-213.5' 0 **Casing Record** None used. **Progress Record** Depth Date 0-74.5' 3-6-79 74.5-173.5' 3-7-79 173.5-213.5' 3-8-79 **Hole Completion** Hole backfilled with concrete 3-8-79. **Water Levels** Taken before hole was completed. Depth Date 8.5' 3-7-79 31.0' 3-8-79	8x Water Hq	90 80 30 71 90 95 100 100 95 70 100 90 100	#1 0 #2 19.7 #3 40.0 Minus #4 52.8 #5 65.8 #6 80.0	19.2 40.0 52.8 Coal 65.8 80.0 96.2				2668 2650.8 2650.3 2622.8 2622.6 2617.2 2604.2 2573.8 2572.2	2 19.2 19.7 47.2 47.4 52.8 65.8 96.2 97.8			SENTINEL BUTTE MEMBER---PALEOCENE ** 0-19.2' SANDSTONE: tan to brown; damp; weathered; soft; oxidized; fine grained; crumbly; moderate to strong HCl reaction; bedding not discernible; core lengths to 2". 0-2.0' TOPSOIL - dark brown. 19.2-19.7' COAL: brownish black; moist; weathered; soft; crumbly. 19.7-52.8' SANDY SHALE: grayish brown and oxidized to 33'; medium gray 33-52.8'; moist; cuts easily with knife; numerous aandy zones; no HCl reaction; bedding nearly horizontal; core lengths to 24". 47.2-47.4' COAL - black; damp; soft; shaley; slickensided. 52.8-65.8' CLAYEY SANDSTONE: light to medium gray; moist to wet; soft; varies from almost mushy to crumbly; fine grained; shaley 57-59.5'; no HCl reaction; some crossbedding but most bedding nearly horizontal; core lengths to 30". 65.8-96.2' SANDY SHALE: medium gray; moist; cuts easily with knife; very aandy and laminated below 82'; weak to moderate HCl reaction; bedding nearly horizontal; core lengths to 18". 96.2-97.8' SANDY LIMESTONE: light gray; dry; hard; bedding not discernible; core lengths to 5". 97.8-138.7' SHALE: medium gray; damp; trims easily with knife; no HCl reaction; bedding nearly horizontal; core lengths to 24". 106.4' Joint dipping 45°. 115.0' Joint dipping 50°. 126.0' Joint dipping 70°. 132.2' Joint dipping 65°. 138.5' Slickensides dipping 45°. 138.7-149.3' COAL: black; damp; slickensided; brittle; earthy. 149.3-166.5' SHALE: medium to dark gray; damp; trims easily with knife; plastic; air slakes; carbonaceous to 155'; no HCl reaction; bedding nearly horizontal; core lengths to 24". 151.7-152.0' COAL - black; shaley; slickensided. 152.8' Joint dipping 60°. 166.5-173.0' CLAYEY SANDSTONE: light to medium gray; moist; cuts easily with knife; laminated; fine grained; most bedding nearly horizontal; weak HCl reaction; core lengths to 10". 173.0-181.1' SHALE: medium gray; damp; trims with some difficulty; plastic; air slakes; no HCl reaction; bedding

** FT. UNION FORMATION

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: O = Diamond, N = Hayzelline, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

Approx. size of hole (X-series)	Ex = 1-1/2",	Ax = 1-7/8",	Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series)	Ex = 7/8",	Ax = 1-1/8",	Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series)	Ex = 1-13/16",	Ax = 2-1/4",	Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series)	Ex = 1-1/2",	Ax = 1-29/32",	Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE: Rattlesnake Butte Study Area / Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: North Dakota

HOLE NO. DH79-107 — LOCATION: 2550' E. & 60' S. of N.W. Corner Sec. 14, T. 140 N., R. 98 W. — GROUND ELEV.: 2670'± — OIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 3-6-79 — FINISHED: 3-8-79 — DEPTH OF OVERBURDEN: 2.0' — TOTAL DEPTH: 213.5' — BEARING:

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes — LOGGED BY: Parish — LOG REVIEWED BY:

HOLES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		73 50 100 91 67 100 80 83 75 81 100 100	#7 97.8 #8 120.0 #9 149.3 Minus #10 166.5 #11 183.5	120.0 138.7 166.5 Coal 181.1 187.2				2531.3 2520.7 2518.3 2518 2503.5 2497 2488.9 2486.5 2482.8 2475.3 2474	138.7 149.3 151.7 152 166.5 173 181.1 183.5 187.2 194.7 196			nearly horizontal; core lengths to 6". 180.0-181.1' Carbonaceous with numerous slickenaides. 181.0-183.5' COAL: black; wet; brittle; broken. 183.5-187.2' CARBONACEOUS SHALE: dark gray; damp; trims with difficulty; plastic; air slakes; no HCl reaction; bedding nearly horizontal; core lengths to 10". 187.2-194.7' COAL: black; damp; soft; earthy; slickensided; brittle. 194.7-196.0' CARBONACEOUS SHALE: nearly black; damp; difficult to trim with knife; plastic; air slakes; no HCl reaction; bedding nearly horizontal; single core length. 196.0-213.5' SANDSTONE: medium to dark gray; moist; uncemented; soft; cuts easily with knife; fine grained; no HCl reaction; bedding not discernible; core lengths to 18".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: O = Diamond, H = Hayzelline, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

Approx. size of hole (X-series)	Ex = 1-1/2",	Ax = 1-7/8",	Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series)	Ex = 7/8",	Ax = 1-1/8",	Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series)	Ex = 1-13/16",	Ax = 2-1/4",	Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series)	Ex = 1-1/2",	Ax = 1-29/32",	Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE: Rattlesnake Butte Study Area / Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: North Dakota

HOLE NO. DH79-107 — LOCATION: 2550' E. & 60' S. of N.W. Corner Sec. 14, T. 140 N., R. 98 W. — GROUND ELEV.: 2670'± — OIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 3-6-79 — FINISHED: 3-8-79 — DEPTH OF OVERBURDEN: 2.0' — TOTAL DEPTH: 213.5' — BEARING:

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes — LOGGED BY: Parish — LOG REVIEWED BY:

HOLES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100 100	#12 194.7	213.5				2456.5	213.5			

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: O = Diamond, N = Hayzelline, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

Approx. size of hole (X-series)	Ex = 1-1/2",	Ax = 1-7/8",	Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series)	Ex = 7/8",	Ax = 1-1/8",	Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series)	Ex = 1-13/16",	Ax = 2-1/4",	Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series)	Ex = 1-1/2",	Ax = 1-29/32",	Bx = 2-3/8", Nx = 3"

METERS / FEET

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD — NORTH DAKOTA

GEOLOGIC LOG OF DH 79-107

GEOLOGY: L. PARISH — FIELD APPROVAL:
DRAWN: — TECH. APPROVAL:
CHECKED: — APPROVED:

BILLINGS, MONTANA — FEBRUARY 1981 — SHEET 1 OF 1

1305-600-261

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

Rattlesnake Butte Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-108 LOCATION 800'E. & 40'S. of N.W. Corner Sec. 2, T. 140 N., R. 98 W. GROUND ELEV. 2625' ± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-12-79 FINISHED 3-14-79 DEPTH OF OVERBURDEN 1.5' TOTAL DEPTH 234.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOULE ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. Driller R.V. Shaw Method Bx casing drive samples 0-10'. Fishtail wash 10-11'. Hq wire-line core 11-234.5'. Water used as drill fluid. About 10-15% water loss 124.5-164.5'. Casing Record None used. Progress Record Depth Date 0-124.5' 3-12-79 124.5-234.5' 3-13-79 Backfilled 3-14-79 Hole Completion Hole backfilled with concrete 5 -14-79. Water Levels Taken before hole was completed. Depth Date 38.1' 3-13-79 41.7' 3-14-79	Bx Hq	100 100 0 61 89 100 100 80 100 84 100	#1 0 20 #2 21 36.3 #3 37 47.7 #4 48.9 63.7 #5 63.7 84 #6 84 103.8					2623.5 2605 2604 2600.5 2588.7 2588 2585 2580.6 2577.3 2576.1 2561.3 2539.5	1.5 10 20 21 24.5 30 36.3 37 40 44.4 47.7 48.9 50 60 63.7 70 80 90			SENTINEL BUTTE MEMBER----PALEOCENE** 0-20.0' SHALE: brown; damp; weathered; oxidized; cuts easily with knife; sandy below 18'; bedding nearly horizontal; weak HCl reaction; core lengths to 12". 0-1.5' TOPSOIL - dark brown. 20.0-21.0' LIMESTONE: dirty white; dry; hard but can barely be trimmed with knife; weathered; sandy; bedding not discernible; core lengths to 6". 21.0-24.5' CLAYEY SANDSTONE: brown; damp; oxidized; edges of core break easily; fine grained; weak HCl reaction; minor crossbedding; core lengths to 6". 24.5-36.3' SHALE: grayish brown; damp; trims with some difficulty; plastic; air slakes; scattered 1/4" limey nodules 33.3-34.5'; no HCl reaction except on nodules; bedding nearly horizontal; core lengths to 10". 26.3' Joint dipping 45°. 27.0' Joint dipping 45°. 34.0' Joint dipping 45°. 34.5' Joint dipping 45°. 36.3-37.0' COAL: black; hard; brittle; broken. 37.0-40.0' SHALE: medium gray; damp; trims with some difficulty; plastic; air slakes; no HCl reaction; bedding nearly horizontal; core lengths to 14". 40.0-44.4' CLAYEY SANDSTONE: light gray; damp; edges break easily with fingers; fine grained; laminated; no HCl reaction; crossbedded; core lengths to 15". 44.4-47.7' SHALE: medium gray; damp; trims easily with knife; plastic; air slakes; no HCl reaction; bedding nearly horizontal; core lengths to 8". 47.7-48.9' COAL: brownish black; brittle; woody; broken. 48.9-63.7' SANDY SHALE: medium gray; moist; firm; trims easily with knife; contains a few plastic zones which air slake; no HCl reaction; scattered sandstone lenses; bedding nearly horizontal; core lengths to 15". 63.7-103.8' SANDSTONE: medium gray; wet; uncemented; loose to crumbly; fine grained; no HCl reaction; bedding not discernible; core lengths to 10". 77.5-78.7' CALCAREOUS SANDSTONE - light gray; dry; cemented; hard. 103.8-114.7' COAL: brownish black; brittle; woody; broken. 114.7-142.0' SILTY SHALE: light grayish brown with darker laminae; damp; trims with some difficulty; a few sandy zones; some pyrite nodules near 120'; no HCl reaction; core lengths to 12".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

** FT. UNION FORMATION

FEATURE Rattlesnake Butte Study Area PROJECT EMRIA No. 22 STATE N. Dak. SHEET 1 OF 3 HOLE NO. DH79-108
Dickinson Coalfield

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-108 LOCATION 800'E.&40'S. of N.W. Corner Sec. 2, T. 140 N., R. 98 W. GROUND ELEV. 2625' ± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-12-79 FINISHED 3-14-79 DEPTH OF OVERBURDEN 1.5' TOTAL DEPTH 234.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOULE ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100 100 #7 114.7 130 100 87 #8 130 142 100 #9 142 147.8 100 #10 148.5 158.9 100 82 #11 158.9 170 93 93 #12 170 192.2 80 75 #13 194.9 201.3						2521.2 2510.3 2483 2477.2 2476.5 2469.5 2466.1 2455 2432.8 2430.1	103.8 110 114.7 120 130 140 142 147.8 148.5 150 155.5 158.9 160 170 180 190 192.2 194.9			142.0-147.8' SHALE: medium gray; damp; trims with difficulty; plastic; air slakes; no HCl reaction; bedding nearly horizontal; core lengths to 18". 147.8-148.5' LIMESTONE: light gray; dry; hard; sandy; bedding not discernible; single core length. 148.5-155.5' SHALE: medium gray; damp; trims with some difficulty; plastic; air slakes; no HCl reaction; bedding nearly horizontal; core lengths to 18". 155.5-158.9' CARBONACEOUS SHALE: black; damp; trims with difficulty; plastic; air slakes; numerous slickensides; no HCl reaction; bedding not discernible; core lengths to 6". 158.9-170.0' SILTY SHALE: light to medium greenish gray; damp; trims easily with knife; somewhat sandy; no HCl reaction; bedding not discernible; core lengths to 20". 170.0-192.2' CLAYEY, CARBONACEOUS SANDSTONE: dark gray; wet; uncemented; crumbly to loose; fine grained; no HCl reaction; bedding not discernible; core lengths to 6". 192.2-194.9' SANDSTONE: light gray; dry; calcareous cemented; hard; fine grained; bedding not discernible; core lengths to 24". 194.9-201.3' CLAYEY SANDSTONE: medium gray; wet; uncemented; cuts easily with knife; fine grained; no HCl reaction; bedding not discernible; core lengths to 20". 201.3-202.5' COAL: black; damp; brittle; woody. 202.5-204.5' SHALE: dark gray; damp; difficult to trim with knife; plastic; air slakes; no HCl reaction; bedding not discernible; core lengths to 10". 204.5-213.3' CLAYEY SANDSTONE: medium gray; wet; uncemented; cuts easily with knife; fine grained; no HCl reaction; bedding not discernible; core lengths to 6". 213.3-220.5' COAL: black; moist; brittle; woody; broken. 220.5-222.3' CLAYEY SANOSTONE: medium gray; damp; uncemented; cuts with some difficulty; fine grained; no HCl reaction; bedding not discernible; core lengths to 12". 222.3-234.5' CARBONACEOUS SHALE: dark gray; damp; difficult to trim with knife; plastic; air slakes; scattered slickensides; no HCl reaction; bedding nearly horizontal; core lengths to 18".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area PROJECT EMRIA No. 22 STATE N. Dak. SHEET 2 OF 3 HOLE NO. DH79-108
Dickinson Coalfield

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-108 LOCATION 800'E.&40'S. of N.W. Corner Sec. 2, T. 140 N., R. 98 W. GROUND ELEV. 2625' ± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-12-79 FINISHED 3-14-79 DEPTH OF OVERBURDEN 1.5' TOTAL DEPTH 234.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOULE ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		90 #14 202.5 213.3 50 100 #15 220.5 234.5 100						2423.7 2422.5 2420.5 2411.7 2404.5 2402.7 2398.6 2398.1 2393.4 2393 2390.5	201.3 202.5 204.5 210 213.3 220 220.5 222.3 226.4 226.9 230 231.6 232.0 234.5 240			226.4-226.9' COAL - black; damp; brittle; shaley. 231.6-232.0' COAL - black; damp; shaley.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area PROJECT EMRIA No. 22 STATE N. Dak. SHEET 3 OF 3 HOLE NO. DH79-108
Dickinson Coalfield

METERS / FEET

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD — NORTH DAKOTA

GEOLOGIC LOG OF DH 79-108

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-262

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-109 LOCATION 3170' N. & 210' W. of S.E. Corner ...Sec. 18, T. 140 N., R. 98 W. GROUND ELEV. 2655' ± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-14-79 FINISHED 3-20-79 DEPTH OF OVERBURDEN 2.0' TOTAL DEPTH 137.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. **Driller** R.V. Shaw **Method** 8x casing drive samples 0-10'. Fishtail wash 10-11'. Hq wireline core 11-137.5'. Water used as drill fluid. Water losses noted below: Depth — %Loss 30' — 80% 44.5-84.5' — 80% Most of water came back in hole when pump was shut off. Hole tended to squeeze near top. **Casing Record** None used. **Progress Record** Depth — Date 0-44.5' — 3-14-79 44.5-84.5' — 3-15-79 84.5-137.5' — 3-20-79 **Hole Completion** Hole backfilled with concrete 3-20-79. **Water Levels** Taken before hole was completed. Depth — Date 27.0' — 3-15-79 26.5' — 3-20-79	8x 10 Fishtail Hq	80 70 0 88 86 100 100 100 75 100 87 100 95	#1 0	16				2653 2639 2638.1 2637.2 2630.5 2629.2 2625.5 2625 2624.5 2608.5 2603.6 2599 2597.5 2585 2563.2 2560.8	2 16 16.9 17.8 24.5 25.8 29.5 30.5 46.5 51.4 56 57.5 70 91.8 94.2			SENTINEL BUTTE MEMBER---PALEOCENE** 0-16.0' SHALE: medium grayish brown 0-10'; light greenish gray 10-16'; weathered; firm; cuts easily with knife; damp; plastic; air slakes below 10'; some caliche 1-2'; moderate to weak HCl reaction; bedding nearly horizontal; core lengths to 18". 0-2.0' TOPSOIL - dark brown; slightly organic. 16.0-16.9' COAL: black, moist; soft; shaley. 16.9-17.8' SANDY, CARBONACEOUS SHALE: dark gray; moist; firm; cuts easily with knife; no HCl reaction; scattered 1/4" coal seams; bedding nearly horizontal; core lengths to 8". 17.8-24.5' CLAYEY SANDSTONE: medium gray; damp; crumbled; fine grained; no HCl reaction; bedding not discernible; core lengths to 2". 24.5-25.8' SHALE: medium gray; damp; firm; cuts easily with knife; plastic; laminated; no HCl reaction; bedding nearly horizontal;core lengths to 6". 25.8-29.5' COAL: black; moist; brittle. 29.5-46.5' SHALE: medium gray, moist; firm; cuts easily with knife; no HCl reaction; bedding nearly horizontal; core lengths to 10". 30.0-30.5' COAL AND SHALE - thinly laminated. 38.5-40.0' Numerous slickensides dipping about 45°. 46.5-51.4' SANDY SHALE: medium gray; moist; firm; trims easily with knife; laminated; weak HCl reaction; bedding nearly horizontal; core lengths to 15". 51.4-56.0' SANDSTONE: light gray; damp; edges of core can easily be broken with fingers; very fine grained; no HCl reaction; bedding nearly horizontal; core lengths to 10". 56.0-57.5' SHALE: medium to dark gray; damp; firm; trims easily with knife; carbonaceous near bottom; no HCl reaction; bedding not discernible; core lengths to 8". 57.5-70.0' COAL: black; damp; hard; brittle; core lengths to 6", 68.5-69.0' CARBONACEOUS SHALE - black; damp; plastic; no HCl reaction. 70.0-91.8' SHALE: medium to dark gray; damp; firm; cuts easily with knife; plastic; air slakes; carbonaceous near top; no HCl reaction; bedding not discernible; core lengths to 12". 80.7' Joint dipping 30°.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hayssaltine, S = Shot, C = Chum
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

** FT. UNION FORMATION

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dakota SHEET 1 OF 2 HOLE NO. DH79-109

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-109 LOCATION 3170' N. & 210' W. of S.E. Corner ...Sec. 18, T. 140 N., R. 98 W. GROUND ELEV. 2655' ± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-14-79 FINISHED 3-20-79 DEPTH OF OVERBURDEN 2.0' TOTAL DEPTH 137.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100 100 100 100 83	#6 94.2 minus	116.1 coal				2554 2553.5 2538.9 2535.3 2532 2517.5	101 101.5 116.1 119.7 123 137.5			91.8-94.2' COAL: black; damp; hard; brittle. 94.2-101.0' CLAYEY SANDSTONE: light gray; damp; firm; cuts easily with knife; fine grained; very thin coal laminae near bottom; no HCl reaction; bedding nearly horizontal; core lengths to 15". 101.0-101.5' COAL: brownish black; moist; soft; woody; broken. 101.5-116.1' SHALE: medium gray; damp; firm; trims with some difficulty; no HCl reaction; bedding not discernible; core lengths to 30". 107.8' Slickensides dipping 50°. 110.0-111.5' Sandy, laminated zone. 116.1-119.7' COAL: black; damp; hard; brittle. 119.7-123.0' SANDY SHALE: dark to medium gray; damp; firm; cuts fairly easily with knife; carbonaceous near top; no HCl reaction; bedding nearly horizontal; core lengths to 13" 123.0-137.5' CLAYEY SANDSTONE: light to medium gray; moist; soft; partially crumbled; fine grained; no HCl reaction; bedding nearly horizontal; core lengths to 6".
		#7 119.7		137.5								

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, N = Hayssaltine, S = Shot, C = Chum
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dakota SHEET 2 OF 2 HOLE NO. DH79-109

METERS 0 1 2 3 4 5 6 7 8 9
FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD – NORTH DAKOTA

GEOLOGIC LOG OF DH 79-109

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-263

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT EMRIA No. 22 — STATE North Dakota

HOLE NO. DH79-110 — LOCATION 60' N. & 80' W. of SE. Corner Sec. 20, T. 140 N., R. 98 W. — GROUND ELEV. 2590'± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 3-21-79 — FINISHED 3-22-79 — DEPTH OF OVERBURDEN 2.0' — TOTAL DEPTH 164.5' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 1500 truck-mounted.

Driller
R.V. Shaw

Method
Bx casing drive samples 0-10'. Fishtail wash 10-11'. Hq wire-line core 11-164.5'. Water used as drill fluid. 10-20% water loss below 16'.

Casing Record
None used.

Progress Record

Depth	Date
0-124.5'	3-21-79
124.5-164.5'	3-22-79

Hole Completion
Hole backfilled with concrete 3-22-79.

Water Levels
Taken before hole was completed.

Depth	Date
41.0'	3-22-79

TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING
Bx							2588	2		
							2587	3		
	90									
		#1								
		0	20.0							
		Minus	Coal							
	70						2580	10		
WASH	0									
Hq										
							2575	15		
							2574.5	15.5		
	33									
	88									
		#2								
		20.0	40.0							
	50									
	90									
		#3								
		40.0	64.8							
	95									
							2525.2	64.8		
	95									
	100									
		#4								
		76.2	90.0							
	100									
	95									
	95									
							2513.8	76.2		

SENTINEL BUTTE MEMBER---PALEOCENE**

0-3.0' WEATHERED SHALE: brown; moist; crumbly; strong HCl reaction; bedding not discernible; core lengths to 3".
0-2.0' TOPSOIL- organic.

3.0-10.0' SILTY SANOSTONE: tan; moist; crumbly; very fine grained; scattered gypsum and rust staining; weak to moderate HCl reaction; bedding nearly horizontal; core lengths to 2".

10.0-64.8' SANOY SHALE: medium gray; damp; firm; cuts easily with knife; laminated; scattered sandstone lenses to 2" thick; a few pyrite nodules; no HCl reaction; bedding nearly horizontal; core lengths to 30".
15.0-15.5' COAL- no recovery; driller reported that it was soft and washed away during drilling.
61.0-64.8' Carbonaceous; dark gray.

64.8-76.2' COAL: brownish black; damp; hard; brittle.

76.2-107.5' SANOY SHALE: medium to dark gray; damp; firm; trims eassily with knife; a few pyrite nodules; laminated; scattered lenses of sandstone; no HCl reaction; bedding nearly horizontal; core lengths to 20".
76.2-81.0' Carbonaceous; dark gray.

107.5-109.3' COAL: brownish black; damp; hard; brittle.

109.3-130.0' SHALE: medium gray; damp; firm; trims with some difficulty; laminated; a few sandy zones; no HCl reaction; bedding nearly horizontal; a few plastic zones that air slake; core lengths to 12".
115.5-115.8' COAL- black; damp; hard; brittle.

130.0-136.2' CLAYEY SANOSTONE: light gray; damp; firm; cuts easily with knife fine grained; some crossbedding; no HCl reaction; core lengths to 20".

136.2-149.0' COAL: brownish black; damp; hard; brittle.

149.0-164.5' SANOY SHALE: medium to dark gray; damp; firm; trims with some difficulty; a few plastic zones that air slake; laminated; carbonaceous near top; no HCl reaction; bedding nearly horizontal; core lengths to 24".
155.4-156.1' COAL- black; moist; hard; brittle.

** FT. UNION FORMATION

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoyastellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT EMRIA No. 22 — STATE N. Dak. — SHEET 1 OF 2 — HOLE NO. DH79-110

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT EMRIA No. 22 — STATE North Dakota

HOLE NO. DH79-110 — LOCATION 60' N. & 80' W. of SE. Corner Sec. 20, T. 140 N., R. 98 W. — GROUND ELEV. 2590'± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 3-21-79 — FINISHED 3-22-79 — DEPTH OF OVERBURDEN 2.0' — TOTAL DEPTH 164.5' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING
		#5								
		90.0	107.5							
	100						2482.5	107.5		
							2480.7	109.3		
	45									
							2474.5	115.5		
		#6					2474.2	115.8		
		109.3	125.0							
		Minus	Coal							
	100									
		#7					2460			
		125.0	136.2							
	95									
							2453.8	136.2		
	100									
							2441	149		
	100	#8					2434.6	155.4		
		149.0	164.5				2433.9	156.1		
		Minus	Coal							
	100						2425.5	164.5		

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoyastellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT EMRIA No. 22 — STATE N. Dak. — SHEET 2 OF 2 — HOLE NO. DH79-110

METERS / FEET

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD – NORTH DAKOTA

GEOLOGIC LOG OF DH 79-110

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-264

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

Rattlesnake Butte Study Area

FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota

HOLE NO. DH79-111 LOCATION 120'S.&1850'E. of N.W. Corner Sec. 4, T. 140 N., R. 98W. GROUND ELEV. 2590' ± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 3-22-79 FINISHED 3-23-79 DEPTH OF OVERBURDEN TOTAL DEPTH 184.5' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. **Driller** R.V. Shaw **Method** Bx casing drive samples 0-10'. Fishtail wash 10-11'. Hq wireline core 11-184.5'. Water and Revert used as drill fluid. No water loss noted. **Casing Record** None used. **Progress Record** Depth Date 0-134.5' 3-22-79 134.5-184.5' 3-23-79 **Hole Completion** Hole backfilled with concrete 3-23-79. **Water Levels** Taken before hole was completed. Depth Date 49.0' 3-23-79	8x Hq	46 50 0 89 100 100 20 100 100 100 100 100	#1 0	20.3				2589.5 2569.7 2561.3 2558 2555.5 2504 2503.7	0.5 20.3 28.7 32 34.5 86 86.3			SENTINEL BUTTE MEMBER---- PALEOCENE** 0-20.3' SHALE: grayish brown; moist; firm; cuts easily with knife; weathered; oxidized; very sandy 9-15'; weak HCl reaction; bedding nearly horizontal; core lengths to 15". 0-0.5' TOPSOIL - dark brown. 20.3-28.7' COAL: brownish black; damp; hard; brittle. 28.7-32.0' CLAYEY SANDSTONE: brownish gray; damp; crumbly; fine grained; carbonaceous and shaley near top; no HCl reaction; bedding not discernible; core lengths to 10". 32.0-34.5' SANDY SHALE: light gray; damp; firm; cuts easily with knife; weak HCl reaction; bedding not discernible; core lengths to 14". 34.5-124.5' SANDSTONE: light gray; moist; uncemented; crushes easily - some loose; fine grained; a few thin clayey zones; no HCl reaction; most bedding nearly horizontal; core lengths to 24". 86.0-86.3' COAL - black; soft; crushed; 1¼" diameter pyrite nodule at bottom. 124.5-125.9' CARBONACEOUS SHALE: dark gray; damp; firm; cuts with difficulty; plastic; air slakes; no HCl reaction; bedding not discernible; core lengths to 3". 125.9-129.7' COAL: brownish black; damp; brittle; woody; shaley. 129.7-147.0' SANDY SHALE: medium gray; moist; soft to firm; cuts easily with knife; laminated with sandstone in some zones; carbonaceous and plastic near bottom; no HCl reaction; bedding nearly horizontal; core lengths to 12". 147.0-149.4' COAL: black; damp; hard; brittle. 147.4-148.2' shaley zone with about 1¼" of light gray bentonite. 149.4-159.0' SHALE: medium gray; damp; firm; trims with some difficulty; scattered sandy zones - very fine grained; carbonaceous near bottom; weak HCl reaction; bedding nearly horizontal; core lengths to 36". 159.0-165.9' COAL: black; damp; hard; brittle. 165.9-175.0' CARBONACEOUS SHALE WITH COAL: dark gray to black; damp; consists of dark gray plastic shale and numerous hard brittle coal layers up to 2" thick; unit probably is about 2/3 shale and 1/3 coal by volume; numerous slickensided core breaks;
			#2 28.7	34.5								
			#3 34.5	55.0								
			#4 55.0	75.0								
			#5 75.0 Minus	100.0 Coal								

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... O = Diamond, H = Hoyastellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

**FT. UNION FORMATION

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 1 OF 2 HOLE NO. DH79-111

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

Rattlesnake Butte Study Area

FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota

HOLE NO. DH79-111 LOCATION 120'S.&1850'E. of N.W. Corner Sec. 4, T. 140 N., R. 98W. GROUND ELEV. 2590' ± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 3-22-79 FINISHED 3-23-79 DEPTH OF OVERBURDEN TOTAL DEPTH 184.5' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100 100 100 100 95 100 100 100	#6 100.0	124.5				2464.1 2460.3 2443 2440.6 2431 2424.1 2415 2407 2405.5	124.5 125.9 129.7 147 149.4 159 165.9 175 183 184.5			bedding nearly horizontal; core lengths to 15". 175.0-183.0' CARBONACEOUS SHALE: dark gray; damp; firm; cuts with some difficulty; plastic; air slakes; scattered slickensides; bedding not discernible; no HCl reaction; core lengths to 18". 181.5-181.7' COAL - black; brittle; shaley. 183.0-184.5' CLAYEY SANDSTONE: light gray; damp; firm; cuts easily with knife; very fine grained; no HCl reaction; bedding not discernible; core lengths to 10".
			#7 124.5 Minus	147.0 Coal								
			#8 149.4	159.0								
			#9 175.0	184.5								

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... O = Diamond, N = Hoyastellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 2 OF 2 HOLE NO. DH79-111

METERS / FEET

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 79-111

GEOLOGY L. PARISH FIELD APPROVAL
DRAWN TECH. APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-265

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-112 LOCATION 90' N. & 120' W. of SE. Corner Sec. 6, T. 140 N., R. 98 W. GROUND ELEV. 2635'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-26-79 FINISHED 3-27-79 DEPTH OF OVERBURDEN 2.0' TOTAL DEPTH 204.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. Driller R.V. Shaw Method 8x casing drive samples 0-10'. Fishtail wash 10-11'. Hq wire-line core 11-204.5'. Water and Revert used as drill fluid. About 30% of fluid lost below 38'. Driller had trouble picking up core. Casing Record None Used. Progress Record Depth Date 0-114.5' 3-26-79 114.5-204.5' 3-27-79 Hole Completion Hole backfilled with concrete 3-27-79. Water Levels Taken before hole was completed. Depth Date 34.0' 3-27-79		80 60 0 83 89 80 85 65 100 100 88 20 100	#1 0 17.0 #2 17.0 34.3 #3 38.9 58.0 #4 58.0 68.0 #5 68.0 78.5 #6 78.5 99.2					2633 2600.7 2596.1 2577 2567 2556. 2550.5 2540.5 2535.8	2 34.4 38.9 58 68 78.5 84.5 94.5 99.2			SENTINEL BUTTE MEMBER----PALEOCENE** 0-34.3' SANDSTONE: brown and clayey 0-4'; grayish brown and relatively clean 4-34.3'; moist; weathered; oxidized; loose to crumbly; fine grained; strong HCl reaction 0-4; no HCl reaction 4-34.3'; bedding nearly horizontal; core lengths to 16". 0-2.0' TOPSOIL- dark brown. 34.3-38.9' COAL: black; moist; hard; brittle; woody. 38.9-58.0' SHALE: medium grsy; moist; firm; cuts easily with knife; plastic; numerous slickensides to 41'; bedding nearly horizontal; core lengths to 30". 58.0-68.0' CARBONACEOUS SHALE: dark gray to black; damp; firm; trims with some difficulty; plastic; air slakes; no HCl reaction; laminated near top; bedding nearly horizontal; core lengths to 18". 68.0-78.5' SHALE: medium gray; damp; firm; trims with some difficulty; plastic; laminated; a few pyrite nodules; no HCl reaction; bedding nearly horizontal; core lengths to 30". 78.5-84.5' CARBONACEOUS SHALE: dark gray to nearly black; damp; trims with some difficulty; plastic; air slakes; laminsted; no HCl reaction; bedding nearly horizontal; core lengths to 18". 79.5-80.5' Several slickensides dipping about 45°. 84.5-94.5' SANDSTONE: poor recovery; medium gray; wet; looae; fine grsined; no HCl reaction; bedding not discernible. 94.5-99.2' SHALE: medium gray; damp; firm; trims with some difficulty; laminsted; no HCl reaction; bedding nearly horizontal; core lengths to 18". 99.2-119.5' SANDSTONE: medium gray; moist; loose to crumbly; fine grained; no HCl reaction; bedding not discernible; core lengths to 14". 119.5-138.5' SHALE: medium gray; damp; firm; trims with some difficulty; plastic; air slakes; no HCl reaction; bedding nearly horizontal; carbonaceous near bottom; core lengths to 24". 136.4' Slickensides dipping 50°. 138.5-145.0' COAL: black; damp; hard; brittle. 145.0-152.0' CARBONACEOUS SHALE: dark gray; damp; firm; trims with some difficulty; plastic; air slakes; no HCl reaction; numerous slickensided core breaks; bedding nearly horizontal; core lengths to 8".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

**FT. UNION FORMATION

FEATURE Rattlesnake Butte Study Area PROJECT EMRIA No. 22 STATE N. Dak. SHEET 1 OF 3 NOLE NO. DH79-112
Dickinson Coalfield

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-112 LOCATION 90' N. & 120' W. of SE. Corner Sec. 6, T. 140 N., R. 98 W. GROUND ELEV. 2635'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-26-79 FINISHED 3-27-79 DEPTH OF OVERBURDEN 2.0' TOTAL DEPTH 204.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100 100 75 100 85 100 100 100 100	#7 99.2 119.5 #8 119.5 138.5 #9 145.0 165.0 #10 165.0 181.8 #11 182.0 204.5					2515.5 2496.5 2490.0 2483.0 2457.7 2453.2 2453.0	119.5 138.5 145 152 177.3 181.8 182.0			152.0-177.3' SHALE: greenish gray; damp; firm; cuts fairly easily with knife; plastic; a few sandy zones, eapecially near bottom; no HCl reaction; bedding nearly horizontal; core lengths to 18". 154.0' Slickensides dipping 45°. 163.0' Slickensides dipping 60°. 164.2' Slickensides dipping 45°. 177.3-181.8' CLAYEY SANDSTONE: laminated dark gray and black; damp; edges of core crumble fairly easily; fine grained; numerous carbonaceous laminae; no HCl reaction; bedding nearly horizontal; core lengths to 24". 181.8-182.0' COAL: brownish black; moist; aandy; seft. 182.0-204.5' SANDSTONE: medium gray; moist; uncemented; crumbles easily; fine grained; no HCl reaction; some crossbedding; core lengths to 14".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area PROJECT EMRIA No. 22 STATE N. Dak. SHEET 2 OF 3 NOLE NO. DH79-112
Dickinson Coalfield

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-112 LOCATION 90' N. & 120' W. of SE. Corner Sec. 6, T. 140 N., R. 98 W. GROUND ELEV. 2635'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-26-79 FINISHED 3-27-79 DEPTH OF OVERBURDEN 2.0' TOTAL DEPTH 204.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
								2430.5	204.5			

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area PROJECT EMRIA No. 22 STATE N. Dak. SHEET 3 OF 3 NOLE NO. DH79-112
Dickinson Coalfield

METERS 0 1 2 3 4 5 6 7 8 9
FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD — NORTH DAKOTA

GEOLOGIC LOG OF DH 79-112

GEOLOGY L.PARISH FIELD APPROVAL
DRAWN TECH. APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY 1981 SHEET 1 OF 1

1305-600-266

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-113 LOCATION 2000' N. & 100' W. of SE. Corner Sec. 10, T. 140 N., R. 99 W. GROUND ELEV. 2680'+ DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-28-79 FINISHED 4-3-79 DEPTH OF OVERBURDEN 0.5' TOTAL DEPTH 204.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOI/B ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. **Driller** R.V. Shaw **Method** Bx casing drive samples 0-10'. Fishtail wash 10-12'. Hq wireline core 12-204.5'. Water used as drill fluid. No water loss noted. **Casing Record** None Used. **Progress Record** Depth Date 0-101.0' 3-28-79 101.0-204.5' 3-29-79 Backfilled 4-3-79 **Hole Completion** Hole backfilled with concrete 4-3-79. **Water Levels** Taken before hole was stabilized. Depth Date 22.5' 3-29-79 29.0' 4-3-79	Bx Hq wash	50 40 0 63 100 80 40 100 100 70 100 55 62	#1 0 Minus	28.5 Coal #2 28.5 #3 63.0 #4 87.6	53.0 86.8 98.8				2679.5 2664.7 2664.2 2651.5 2627 2617 2593.2 2592.4 2585.5 2581.2	0.5 15.3 15.8 28.5 53 63 86.8 87.6 94.5 98.8			SENTINEL BUTTE MEMBER----PALEOCENE** 0-15.3' CLAYEY SANDSTONE: poor recovery; light gray; damp; firm; cuts easily with knife; weathered; oxidized; fine grained; some caliche near 10'; generally weak HCl reaction; bedding not discernible; core lengths to 5'. 0-0.5 TOPSOIL- brown. 15.3-15.8' COAL: highly weathered; brownish black; moist; soft; crumbled; almost like black dirt. 15.8-28.5' SHALE: medium brownish gray; damp; firm; cuts easily with knife; oxidized; very weak HCl reaction; bedding nearly horizontal; core lengths to 15". 28.5-53.0' SANDY SHALE: medium gray; damp; firm; cuts easily with knife; laminated; no HCl reaction; some cross bedding but most bedding nearly horizontal; scattered slickensides and distorted coaly laminae 42-44"; core lengths to 12". 53.0-63.0' COAL: black; damp; hard; brittle. 63.0-86.8' SHALE: medium to dark gray; damp; firm; varies from easy to cut with knife near top to difficult to cut near bottom; no HCl reaction; scattered laminated sandy zones; bedding nearly horizontal; core lengths to 20". 84.0-86.8' Carbonaceous- dark gray. 86.8-87.6' COAL: brownish black; damp; hard; brittle. 87.6-94.5' SHALE: medium gray; moist; firm; cuts easily with knife; no HCl reaction; bedding not discernible; core lengths to 4". 94.5-98.8' SANDSTONE: light gray; damp; uncemented; edges break easily; fine grained; no HCl reaction; coaly laminae 98.3-98.5'; bedding usually nearly horizontal; core lengths to 18". 98.8-101.0' CALCAREOUS SANDSTONE: light gray; dry; hard; fine grained; strong HCl reaction; bedding not discernible; core lengths to 10". 101.0-102.6' COAL and SANDSTONE: thinly laminated coal and sandstone layers; damp; fine grained; no HCl reaction; bedding nearly horizontal; core lengths to 6". 102.6-113.1 SHALE: medium gray; damp; firm; trims fairly easily with knife; plastic; no HCl reaction; bedding nearly horizontal; core lengths to 18". 113.1-113.5' COAL: black; damp; hard; brittle.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

** FT. UNION FORMATION

FEATURE Rattlesnake Butte Study Area Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 1 OF 3 HOLE NO. DH79-113

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE North Dakota
HOLE NO. DH79-113 LOCATION 2000' N. & 100' W. of SE. Corner Sec. 10, T. 140 N., R. 99 W. GROUND ELEV. 2680'+ DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-28-79 FINISHED 4-3-79 DEPTH OF OVERBURDEN 0.5' TOTAL DEPTH 204.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOI/B ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		60 100 90 73 55 80 100 100 100 100	#5 102.6 #6 113.5 #7 129.0 #8 143.0 #9 160.0 #10 174.5	113.1 127.6 143.0 160.0 174.5 200.5				2579 2577.4 2566.9 2566.5 2559.5 2556 2552.4 2551 2537	101 102.6 113.1 113.5 120.5 124 127.6 129 143			113.5-120.5' SHALE: greenish gray; moist; firm; trims fairly easily with knife; no HCl reaction; bedding not discernible; core lengths to 24". 120.5-124.0' SANDSTONE: medium gray; wet; soft; loose; fine grained; no HCl reaction; bedding not discernible. 124.0-127.6' SHALE: dark gray; damp; firm; difficult to trim with knife; carbonaceous and plastic near bottom; no HCl reaction; bedding nearly horizontal; core lengths to 14". 127.6-129.0' COAL: brownish black; damp; hard; woody; brittle. 129.0-143.0' CLAYEY SANDSTONE: light gray; moist; firm; cuts easily with knife; fine grained; laminated with a few widely scattered coal layers; no HCl reaction; bedding nearly horizontal; core lengths to 10". 143.0-200.5' SANDSTONE: medium gray; wet; loose to firm; all uncemented; scattered clayey zones; fine grained; no HCl reaction; bedding nearly horizontal; core lengths to 20". 200.5-204.5' SHALE ?: no recovery; driller reported gray shale cuttings.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 2 OF 3 HOLE NO. DH79-113

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

Rattlesnake Butte Study Area
FEATURE Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak.
HOLE NO. DH79-113 LOCATION 2000' N. & 100' W. of SE. Corner Sec. 10, T. 140 N., R. 99 W. GROUND ELEV. 2680'+ DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-28-79 FINISHED 4-3-79 DEPTH OF OVERBURDEN 0.5' TOTAL DEPTH 204.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOI/B ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		0						2479.5 2475.5	200.5 204.5			

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... O = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area Dickinson Coalfield PROJECT EMRIA No. 22 STATE N. Dak. SHEET 3 OF 3 HOLE NO. DH79-113

METERS 0 1 2 3 4 5 6 7 8 9
FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD – NORTH DAKOTA

GEOLOGIC LOG OF DH 79-113

GEOLOGY L. PARISH FIELD APPROVAL
DRAWN TECH. APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-267

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Rattlesnake Butte Study Area — PROJECT EMRIA No. 22 — STATE North Dakota

HOLE NO. DH79-114 — LOCATION 50' S. & 575' E. of NW. Corner Sec. 22, T. 140 N., R. 99 W. — GROUND ELEV. 2610'± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 4-3-79 — FINISHED 4-4-79 — DEPTH OF OVERBURDEN 1.0' — TOTAL DEPTH 134.5' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. **Driller** R.V. Shaw **Method** 8x casing drive samples 0-10'. Fishtail wash 10-11'. Hq wire-line core 11-134.5'. Water used as drill fluid. 10-20% water loss noted. **Casing Record** None used. **Progress Record** Depth Date 0-114.5' 4-3-79 114.5-134.5' 4-4-79 **Hole Completion** Backfilled with concrete 4-4-79. **Water Level** Taken before hole was completed. Depth Date 17.5' 4-4-79		90 40 0 57 69 100 100 60 90 90 100	#1 0 #2 11.5 #3 25.0 #4 45.4 #5 60.0 #6 76.0	10.8 25.0 40.7 60.0 76.0 90.5				2609 2599.2 2598.5 2569.3 2564.6 2534 2519.5 2515.5	1 10.8 11.5 40.7 45.4 76 90.5 94.5			SENTINEL BUTTE MEMBER---PALEOCENE** 0-10.8' CLAYEY SAND: light brown; damp; firm; edges of core crumble easily; fine grained; weathered; oxidized; moderate HCl reaction; bedding not discernible; core lengths to 4". 0-1.0' TOPSOIL- dark brown. 10.8-11.5' COAL: brownish black; moist; very soft; like black dirt. 11.5-40.7' SHALE: brownish gray to 14'; medium gray 14-40.7'; damp; firm; trims fairly easily with knife; plastic; carbonaceous at bottom; no HCl reaction; bedding nearly horizontal; core lengths to 18". 40.7-45.4' COAL: brownish black; damp; reasonably hard; brittle; very shaley below 43'. 45.4-76.0' CLAYEY SANDSTONE: medium gray; damp; firm; edges of core break easily; very clayey; fine grained; no HCl reaction; bedding nearly horizontal; core lengths to 24". 76.0-90.5' SHALE: greenish gray to 82'; medium gray 82-90.5'; damp; firm; trims with some difficulty; no HCl reaction; carbonaceous at bottom; bedding nearly horizontal; core lengths to 18". 90.5-94.5' COAL: brownish black; damp; shaley; hard; brittle. 94.5-101.0' COAL and SHALE: brownish black; damp; reasonably hard; consists of about 50% dark gray, very carbonaceous, plastic shale and 50% brownish black coal. 101.0-109.6' SANDY SHALE: medium gray; damp; firm; trims easily with knife; laminated; no HCl reaction; bedding nearly horizontal; core lengths to 18". 109.6-110.2' COAL: brownish black; damp; hard; brittle. 110.2-121.4' SANDY SHALE: light to medium gray; damp; firm; cuts easily with knife; laminated; zones of fine grained sandstone; carbonaceous near bottom; no HCl reaction; bedding nearly horizontal; core lengths to 20". 121.4-123.5' COAL: brownish black; damp; hard; brittle. 123.5-127.2' SANDY SHALE: light gray; damp; firm; trims with some difficulty; no HCl reaction; bedding not discernible core lengths to 24". 127.2-134.5' CLAYEY SANDSTONE: light gray; damp; firm; edges of core break easily; fine grained; no HCl reaction; mostly crossbedded with dips to 70°; core lengths to 12".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

** FT. UNION FORMATION

FEATURE Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT EMRIA No. 22 — STATE N. Dak. — SHEET 1 OF 2 — HOLE NO. DH79-114

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Rattlesnake Butte Study Area — PROJECT EMRIA No. 22 — STATE North Dakota

HOLE NO. DH79-114 — LOCATION 50'S. & 575'E. of NW. Corner Sec. 22, T. 140 N., R. 99 W. — GROUND ELEV. 2610'± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 4-3-79 — FINISHED 4-4-79 — DEPTH OF OVERBURDEN 1.0' — TOTAL DEPTH 134.5' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100 100 100 100 100 100	#7 101.0 Minus #8 123.5					2509 2500.4 2499.8 2488.6 2486.5 2482.8 2475.5	101 109.6 110.2 121.4 123.5 127.2 134.5			

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . . . D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT EMRIA No. 22 — STATE N. Dak. — SHEET 2 OF 2 — HOLE NO. DH79-114

METERS 0 1 2 3 4 5 6 7 8 9 — FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 79-114

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-268

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: North Dakota

HOLE NO. DH79-115 — LOCATION: 100' S. & 1350' E. of NW. Corner Sec. 24, T. 140 N., R. 99 W. — GROUND ELEV. 2565'± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 4-4-79 — FINISHED: 4-5-79 — DEPTH OF OVERBURDEN: 2.0' — TOTAL DEPTH: 124.5' — BEARING:

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes — LOGGED BY: Parish — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOYLS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drill Failing 1500 truck-mounted. **Driller** R.V. Shaw **Method** Bx casing drive samples 0-10'. Fishtail wash 10-11'. Hq wire-line core 11-124.5'. Water and Revert used as drill fluid. 40-50% of fluid loat. **Casing Record** None used. **Progress Record** Depth — Date 0-94.5' 4-4-79 94.5-124.5' 4-5-79 **Hole Completion** Hole backfilled with concrete 4-5-79. **Water Level** None taken.	NQ (Part) Hq	50 90 0 25 32 80 95 90 95 100 95 100 70	#1 0 #2 20.0 #3 44.8 #4 58.2 #5 80.0	20.0 44.4 55.5 80.0 100.0				2563 2520.6 2520.2 2509.5 2506.8 2504.8	2 44.4 44.8 55.5 58.2 60.2			SENTINEL BUTTE MEMBER---PALEOCENE** 0-2.0' WEATHERED SHALE (TOPSOIL): brown; damp; crumbly; organic; no HCl reaction; bedding not discernible; core lengths to 3". 2.0-44.4' SANDSTONE: light brown; moist; uncemented; looae to firm; oxidized; fine grained; very weak HCl reaction; bedding nearly horizontal; core lengths to 12". 44.4-44.8' COAL: black; damp; hard; brittle. 44.8-55.5' SANDY SHALE: medium gray; damp; firm; cuts easily with knife; very sandy; laminated; no HCl reaction; bedding nearly horizontal; core lengths to 20". 55.5-58.2' COAL: brownish black; damp; hard; brittle; woody. 58.2-60.2' SANDY SHALE: light gray; damp; firm; cuts with some difficulty; no HCl reaction; bedding not discernible; core lengths to 15". 60.2-124.5' SANDSTONE: light gray; moist; uncemented; varies from loose to firm; fine grained; laminated; no HCl reaction; bedding nearly horizontal; core lengths to 20".

** FT. UNION FORMATION

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole	D = Diamond, H = Hoystellite, S = Shot, C = Churn		
Hole sealed	P = Packer, Cm = Cemented, Cs = Bottom of casing		
Approx. size of hole (X series)	Ex = 1-1/2",	Ax = 1-7/8",	Bx = 2-3/8", Nx = 3"
Approx. size of core (X series)	Ex = 7/8",	Ax = 1-1/8",	Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X series)	Ex = 1-13/16",	Ax = 2-1/4",	Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X series)	Ex = 1-1/2",	Ax = 1-29/32",	Bx = 2-3/8", Nx = 3"

FEATURE: Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: N. Dak. — SHEET 1 OF 2 — HOLE NO. DH79-115

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE: Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: North Dakota

HOLE NO. DH79-115 — LOCATION: 100' S. & 1350' E. of NW. Corner Sec. 24, T. 140 N., R. 99 W. — GROUND ELEV. 2565'± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 4-4-79 — FINISHED: 4-5-79 — DEPTH OF OVERBURDEN: 2.0' — TOTAL DEPTH: 124.5' — BEARING:

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes — LOGGED BY: Parish — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOYLS ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		90	#6 100.0	124.5				2440.5	124.5			

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole	D = Diamond, H = Hoystellite, S = Shot, C = Churn		
Hole sealed	P = Packer, Cm = Cemented, Cs = Bottom of casing		
Approx. size of hole (X series)	Ex = 1-1/2",	Ax = 1-7/8",	Bx = 2-3/8", Nx = 3"
Approx. size of core (X series)	Ex = 7/8",	Ax = 1-1/8",	Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X series)	Ex = 1-13/16",	Ax = 2-1/4",	Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X series)	Ex = 1-1/2",	Ax = 1-29/32",	Bx = 2-3/8", Nx = 3"

FEATURE: Rattlesnake Butte Study Area, Dickinson Coalfield — PROJECT: EMRIA No. 22 — STATE: N. Dak. — SHEET 2 OF 2 — HOLE NO. DH79-115

METERS 0 1 2 3 4 5 6 7 8 9 — FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

RATTLESNAKE BUTTE STUDY AREA
DICKINSON COALFIELD — NORTH DAKOTA

GEOLOGIC LOG OF DH 79-115

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981 — SHEET 1 OF 1

1305-600-269

WEATHERING TESTS

Core Samples From Rattlesnake Butte, North Dakota

Sample I.D.	Remarks
Shale DH 78-101 Depth (ft) 24.0-25.0 (R-1)*	See Photographs 6 and 11 Laboratory weathering: Surface slaking and cracking at 5 cycles. Continued slaking at 20 cycles. %BD = 20 Outdoor: Surface cracking at 10 weeks.
Shale DH 78-102 Depth (ft) 208.5-209.5 (R-2)	See photographs 6 and 11 Laboratory weathering: Slaking at 5 cycles. Continued slaking at 20 cycles. %BD = 35 Outdoor: Surface peeling at 10 weeks.
Shale DH 79-105 Depth (ft) 26.5-27.5 (R-3)	See photographs 6 and 11 Laboratory weathering: Surface cracking and slight slaking at 5 cycles. Continued slaking at 20 cycles. %BD = 19 Outdoor: Very slight surface cracking at 10 weeks.
Shale DH 79-105 Depth (ft) 215.0-216.0 (R-4)	See photographs 7 and 12 Laboratory weathering: Severe slaking at 5 cycles. Continued slaking at 20 cycles. %BD = 57 Outdoor: Surface peeling at 10 weeks.
Shale DH 79-106 Depth (ft) 59.0-60.0 (R-5)	See photographs 7 and 12 Laboratory weathering: Surface cracking at 5 cycles. Some slaking at 10 cycles. %BD = 19 Outdoor: Surface cracking at 10 weeks.

* Laboratory sample number

WEATHERING TESTS

Sample I.D.	Remarks
Sandy Siltstone DH 79-106 Depth (ft) 135.0-136.0 (R-6)	See photographs 7 and 12 Laboratory weathering: Swelling, cracking and slaking at 5 cycles. Continued swelling and slaking at 20 cycles. %BD = 76 Outdoor: Slight surface cracking at 10 weeks.
Sandy Shale DH 79-107 Depth (ft) 85.5-86.5 (R-7)	See photographs 8 and 13 Laboratory weathering: Slaking at 5 cycles. Continued slaking at 20 cycles. %BD = 24 Outdoor: No change at 10 weeks.
Clayey Sandstone DH 79-108 Depth (ft) 196.0-197.0 (R-8)	See photographs 8 and 13 Laboratory weathering: Minor cracking and slaking at 5 cycles. Cracking and slaking at 20 cycles. %BD = 15 Outdoor: No change at 10 weeks
Shale DH 79-109 Depth (ft) 8.5-9.5 (R-9)	See photographs 8 and 13 Laboratory weathering: Specimen softens upon wetting, but returns to a hard state after drying. Very little breakdown at 20 cycles. Some salt leaching noted at 20 cycles. %BD = 6 Outdoor: Surface cracking at 10 weeks.
Shale DH 79-109 Depth (ft) 106.0-107.0 (R-10)	See photographs 9 and 14 Laboratory weathering: Swelling and slaking at 5 cycles. Continued swelling and slaking at 20 cycles. %BD = 31 Outdoor: Surface peeling at 10 weeks.

WEATHERING TESTS

Sample I.D.	Remarks
Sandy Shale DH 79-110 Depth (ft) 38.0-39.0 (R-11)	See photographs 9 and 14 Laboratory weathering: Cracking and slaking at 5 cycles. Continued slaking at 20 cycles. %BD = 35 Outdoor: Slight surface cracking at 10 weeks.
Clayey Sandstone DH 79-110 Depth (ft) 131.0-132.0 (R-12)	See photographs 9 and 14 Laboratory weathering: Cracking at 5 cycles. Very little change at 20 cycles. %BD = 9 Outdoor: No change at 10 weeks.
Shale DH 79-113 Depth (ft) 114.0-115.0 (R-13)	See photographs 10 and 15 Laboratory weathering: Severe swelling and slaking at 5 cycles. Continued swelling and slaking at 20 cycles. %BD = 62 Outdoor: Surface peeling at 10 weeks.
Shale DH 79-114 Depth (ft) 32.0-33.0 (R-14)	See photogrpahs 10 and 15 Laboratory weathering: Mushroom appearance at 5 cycles. Slaking and cleaving at 10 cycles. %BD = 39 Outdoor: No change at 10 weeks.
Clayey Sandstone DH 79-114 Depth (ft) 72.0-73.0 (R-15)	See photographs 10 and 15 Laboratory weathering: Specimen friable at 5 cycles. Some breakdown at 20 cycles. %BD = 47 Outdoor: Specimen slightly friable at 10 weeks.

WEATHERING TESTS

Sample I.D.	Remarks
Sandstone DH 79-103 Depth (ft) 70.0-71.0 (R-16)	Sample not tested. It was already broken down when received. %BD = 100
Sandstone DH 79-104 Depth (ft) 70.0-71.0 (R-17)	Sample not tested. It was already broken down when received. %BD = 100
Sandstone DH 79-106 Depth (ft) 170.0-171.0 (R-18)	Sample not tested. It was already broken down when received. %BD = 100
Sandstone DH 79-107 Depth (ft) 205.0-206.0 (R-19)	Sample not tested. It was already broken down when received. %BD = 100
Sandstone DH 79-111 Depth (ft) 72.0-73.0 (R-20)	Sample not tested. It was already broken down when received. %BD = 100

Results of 1-Year Outdoor Weathering for Core Samples
from Rattlesnake Butte, North Dakota

Sample I.D.	Remarks
Shale DH 78-101 Depth (ft) 24.0-25.0 (R-1)*	See photograph 16 Swelling and some slaking at 1 year % BD = 53 % Passing No. 10 screen = 17
Shale DH 78-102 Depth (ft) 208.5-209.5 (R-2)	See photograph 16 Swelling and slaking at 1 year % BD = 100 % Passing No. 10 screen = 40
Shale DH 79-105 Depth (ft) 26.5-27.5 (R-3)	See Photograph 16 Swelling and slaking at 1 year % BD = 100 % Passing No. 10 screen = 28
Shale DH 79-105 Depth (ft) 215.0-216.0 (R-4)	See photograph 17 Swelling and slaking at 1 year % BD = 100 % Passing No. 10 screen = 21
Shale DH 79-106 Depth (ft) 59.0-60.0 (R-5)	See photograph 17 Swelling and some slaking at 1 year % BD = 73 % Passing No. 10 screen = 36
Sandy Siltstone DH 79-106 Depth (ft) 135.0-136.0 (R-6)	See photograph 17 Swelling and some cleavage cracking at 1 year % BD = 37 % Passing No. 10 screen = 25

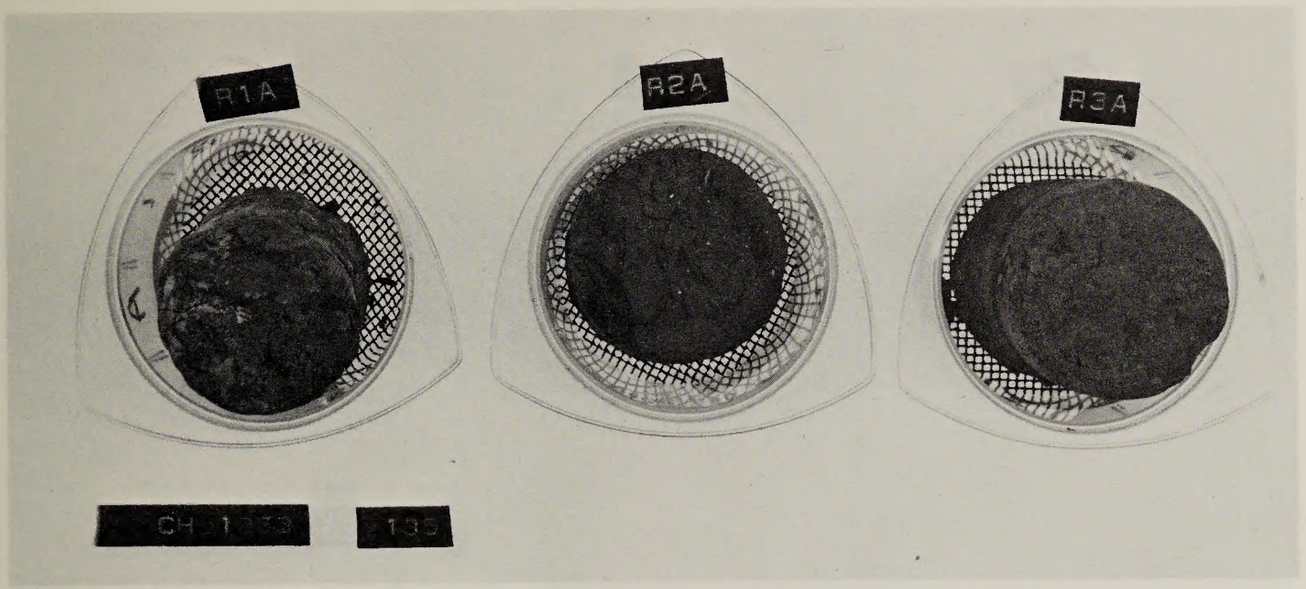
* Laboratory sample number

WEATHERING TESTS

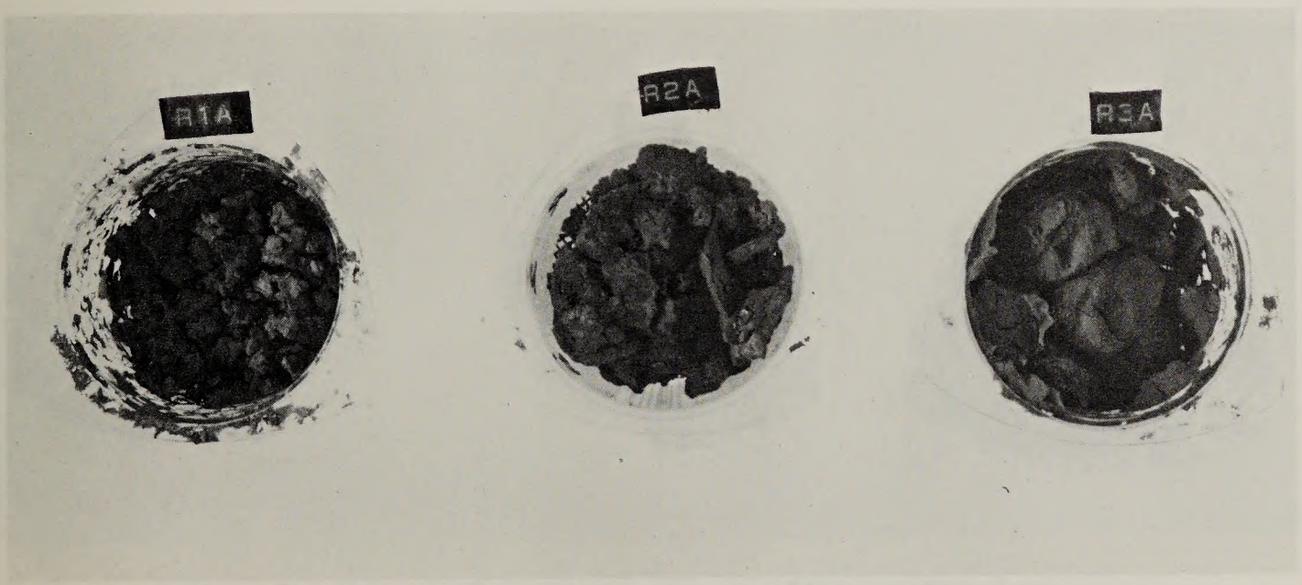
Sandy Shale DH 79-107 Depth (ft) 85.5-86.5 (R-7)	See photograph 18 Swelling and some cracking at 1 year % BD = 24 % Passing No. 10 screen = 23
Clayey Sandstone DH 79-108 Depth (ft) 196.0-197.0 (R-8)	See photograph 18 Specimen friable at 1 year % BD = 32 % Passing No. 10 screen = 14
Shale DH 79-109 Depth (ft) 8.5-9.5 (R-9)	See photograph 18 Swelling and some slaking at 1 year % BD = 38 % Passing No. 10 screen = 17
Shale DH 79-109 Depth (ft) 106.0-107.0 (R-10)	See photograph 19 Swelling and surface cracking at 1 year % BD = 30 % Passing No. 10 screen = 21
Sandy Shale DH 79-110 Depth (ft) 38.0-39.0 (R-11)	See photograph 19 Swelling and some slaking at 1 year % BD = 71 % Passing No. 10 screen = 27
Clayey Sandstone DH 79-110 Depth (ft) 131.0-132.0 (R-12)	See photograph 19 Swelling at 1 year % BD = 48 % Passing No. 10 screen = 30
Shale DH 79-113 Depth (ft) 114.0-115.0 (R-13)	See photograph 20 Swelling and slight slaking at 1 year % BD = 26 % Passing No. 10 screen = 22

WEATHERING TESTS

Shale DH 79-114 Depth (ft) 32.0-33.0 (R-14)	See photograph 20 Swelling and slight surface cracking at 1 year % BD = 12 % Passing No. 10 screen = 12
Clayey Sandstone DH 79-114 Depth (ft) 72.0-73.0 (R-15)	See photograph 20 Swelling and some cleavage cracking at 1 year % BD = 54 % Passing No. 10 screen = 41



a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Photo 6 - Results of weathering tests for shale samples R-1, R-2, and R-3 subjected to 20 laboratory weathering cycles.

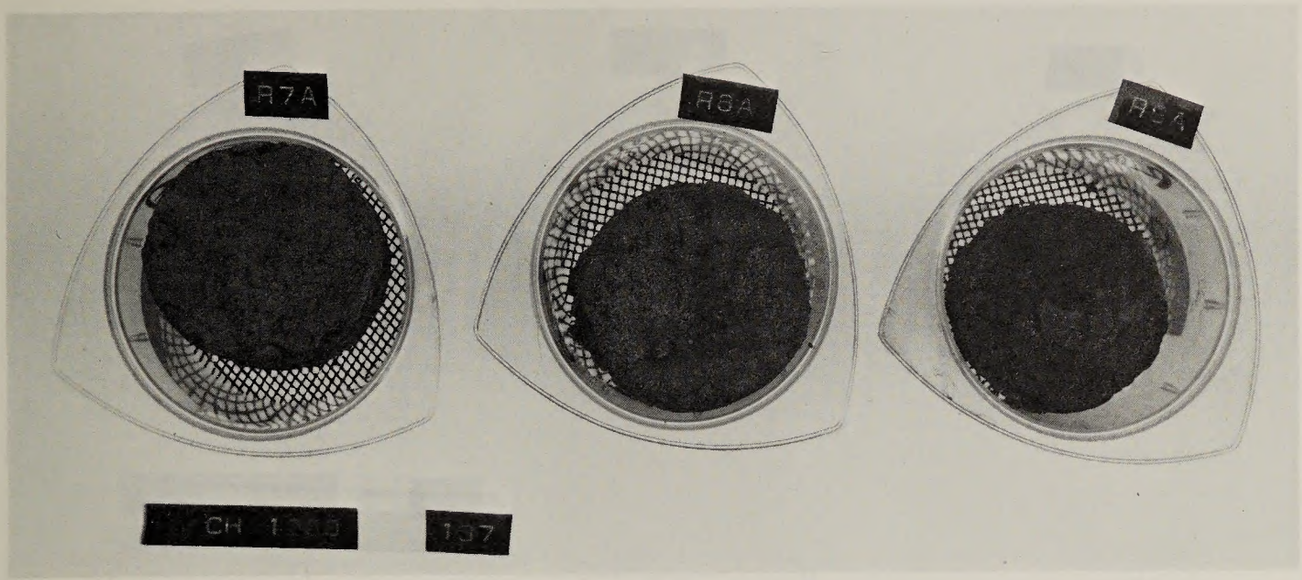


a. Original condition of test specimens.



b. Condition of test specimens after weathering

Photo 7 - Results of weathering tests for shale samples R-4 and R-5, and sandy siltstone sample R-6 subjected to 20 laboratory weathering cycles.

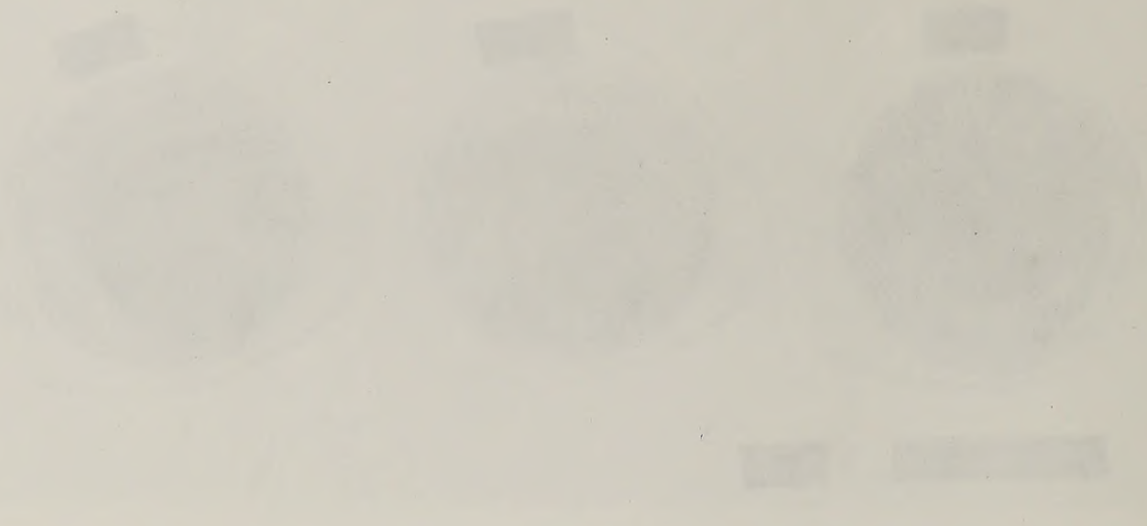


a. Original condition of test specimens.

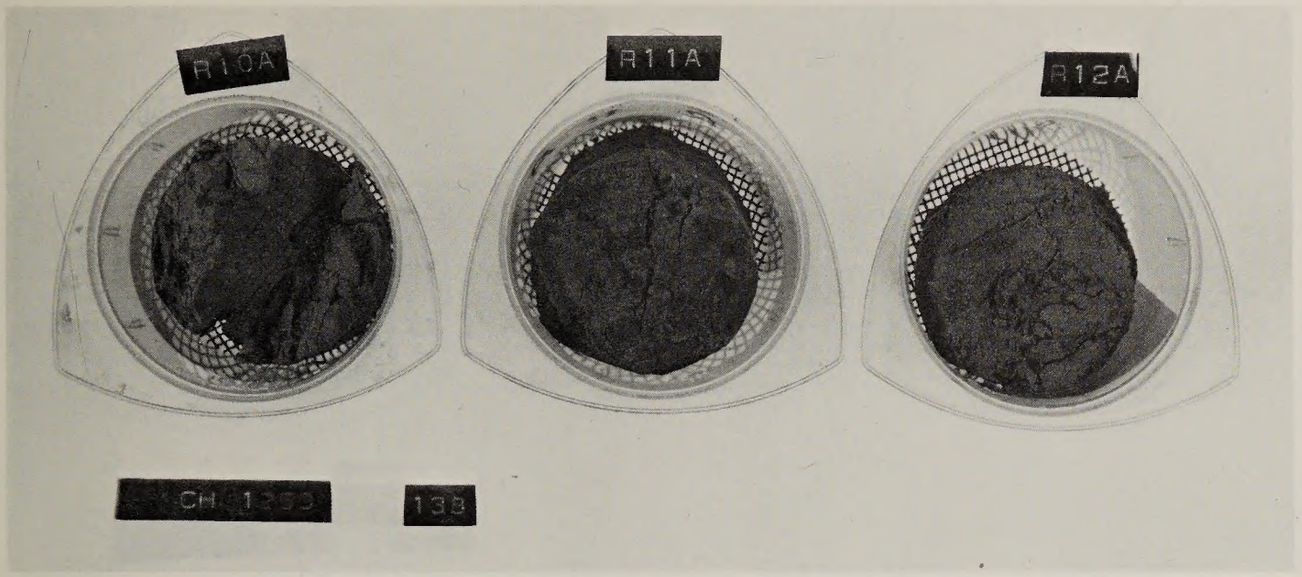


b. Condition of test specimens after weathering.

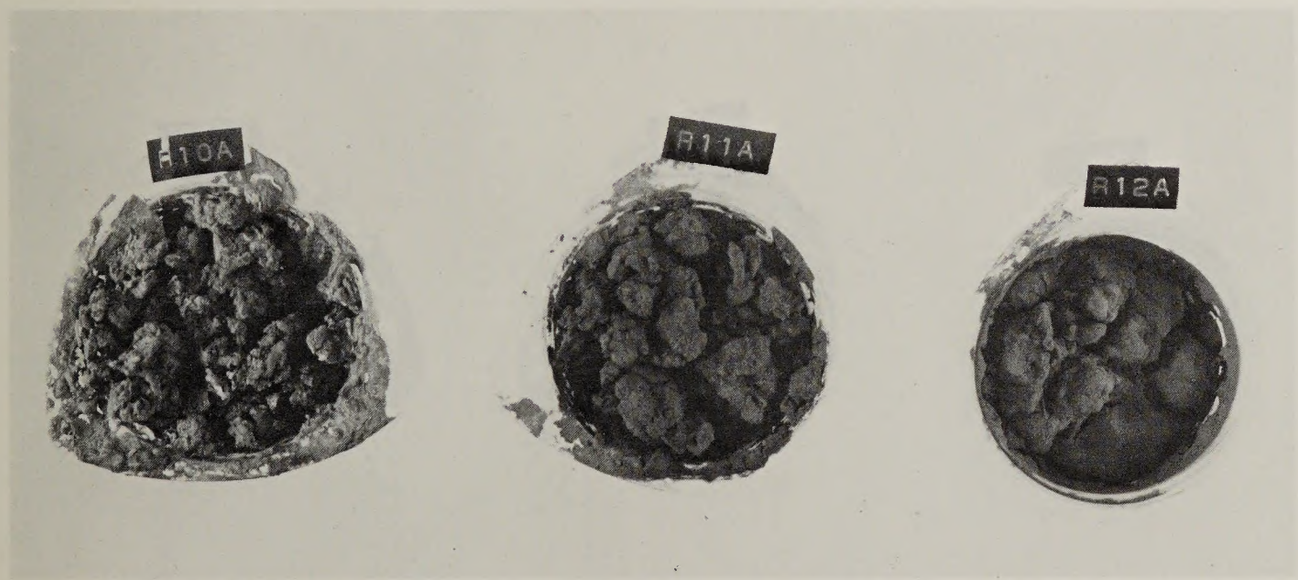
Photo 8 - Results of weathering tests for sandy shale sample R-7, clayey sandstone sample R-8, and shale sample R-9 subjected to 20 laboratory weathering cycles.





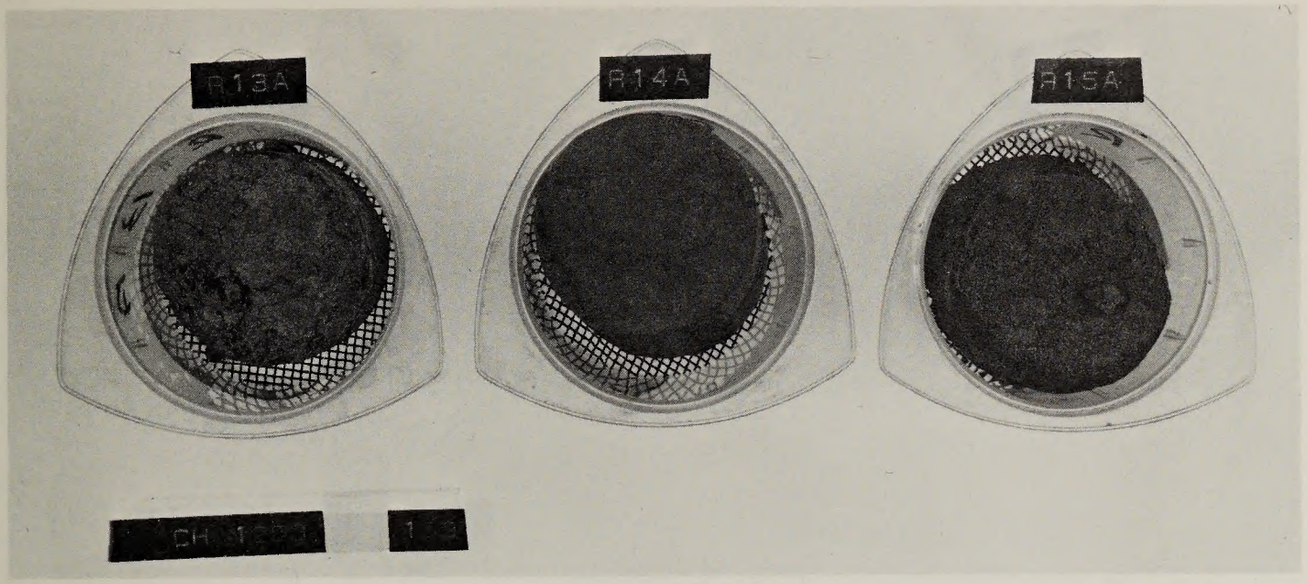


a. Original condition of test specimens.

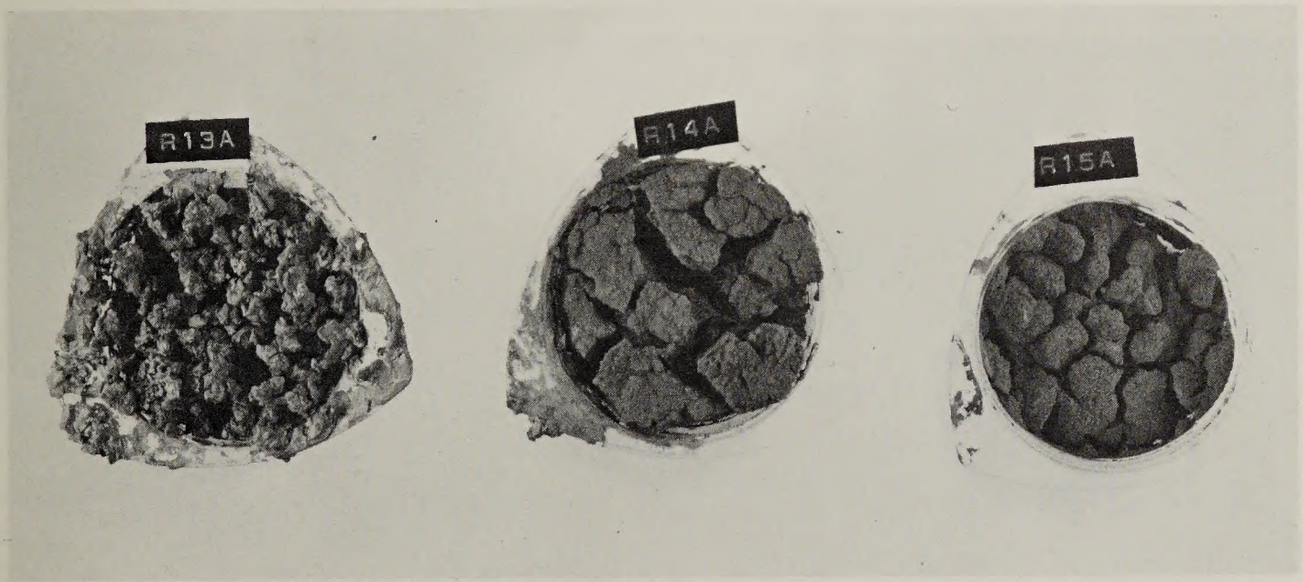


b. Condition of test specimens after weathering.

Photo 9 - Results of weathering tests for shale sample R-10, sandy shale R-11, and clayey sandstone sample R-12 subjected to 20 laboratory weathering cycles.

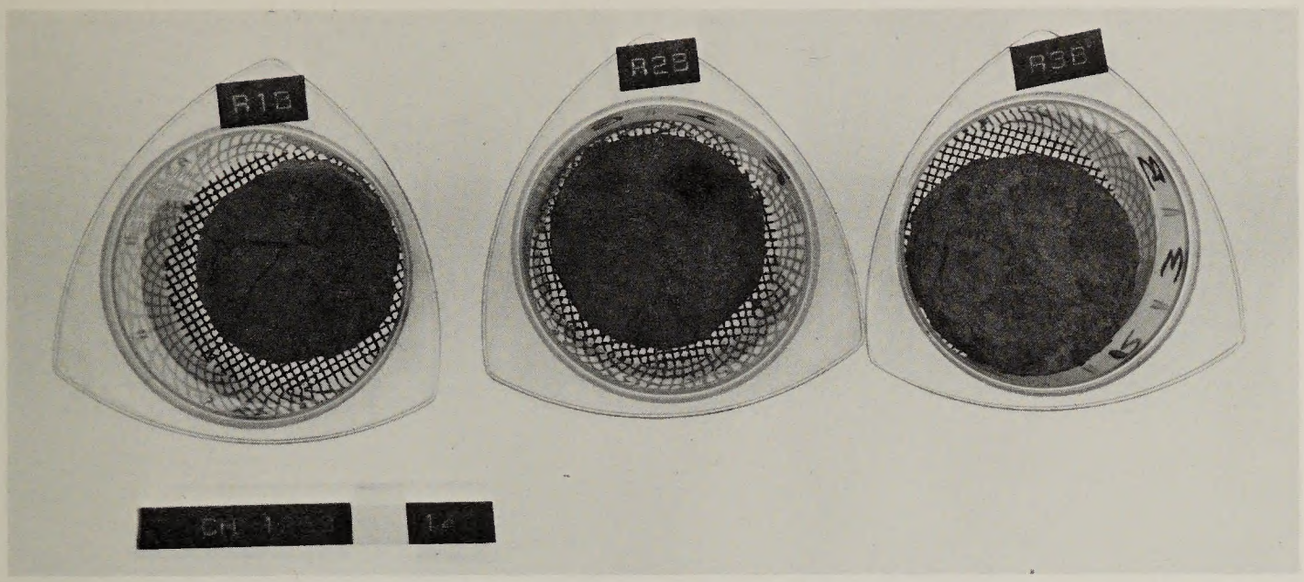


a. Original condition of test specimens



b. Condition of test specimens after weathering.

Photo 10 - Results of weathering tests for shale samples R-13, and R-14, and clayey sandstone sample R-15 subjected to 20 laboratory weathering cycles.

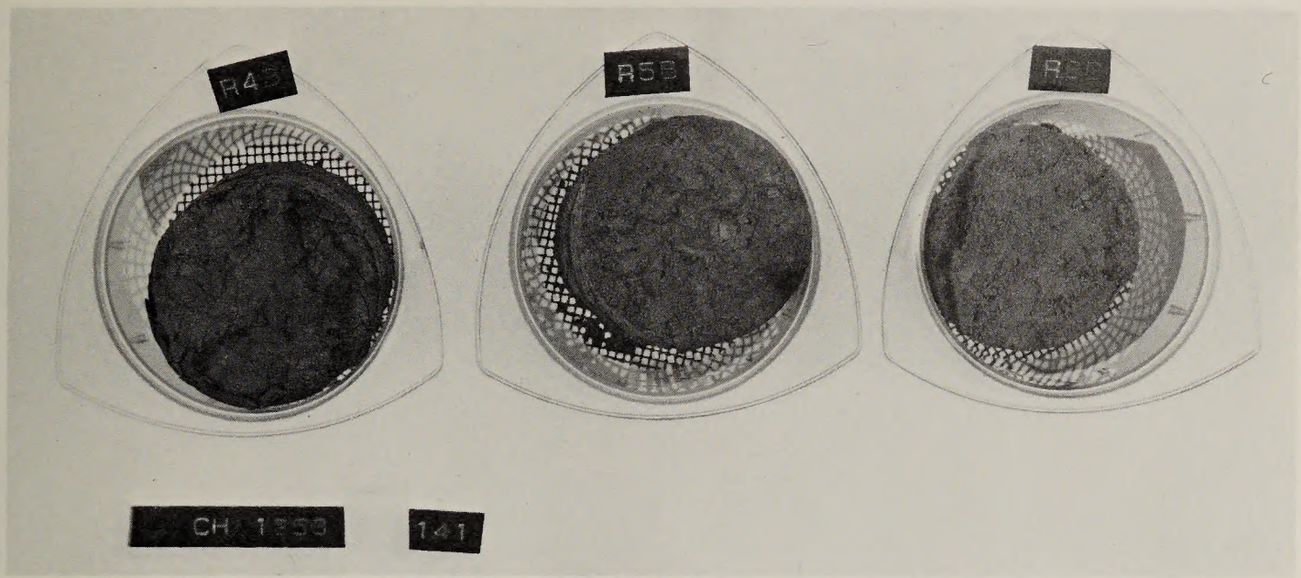


a. Original condition of test specimens.

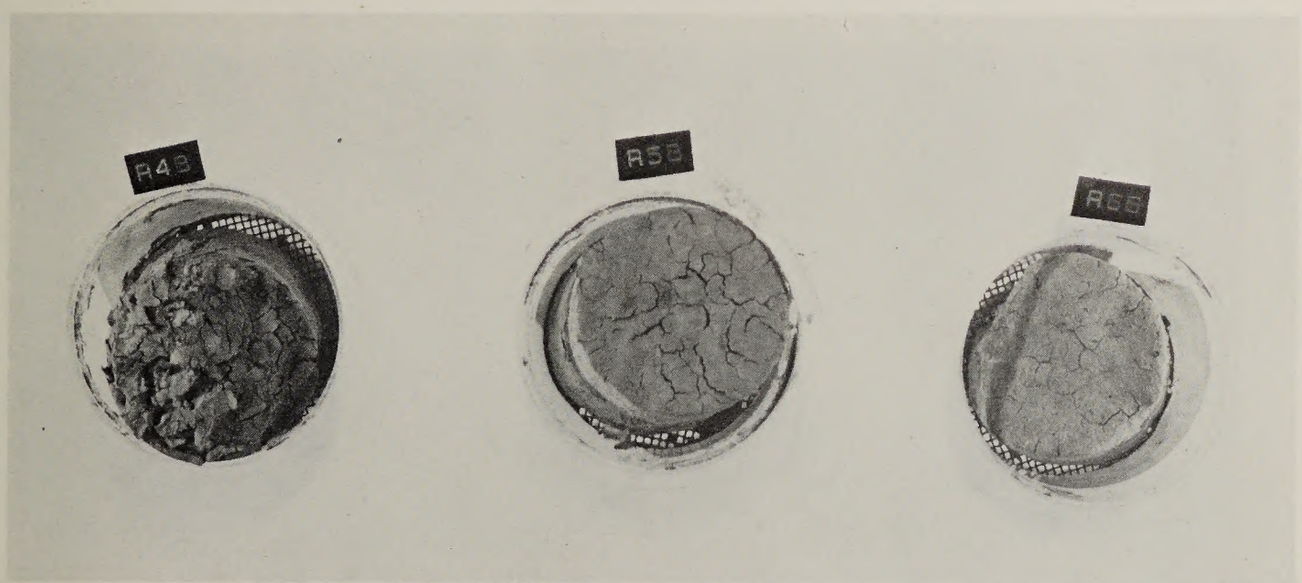


b. Condition of test specimens after weathering.

Photo 11 - Results of weathering tests for shale samples R-1, R-2, and R-3 subjected to 10 weeks of outdoor exposure.

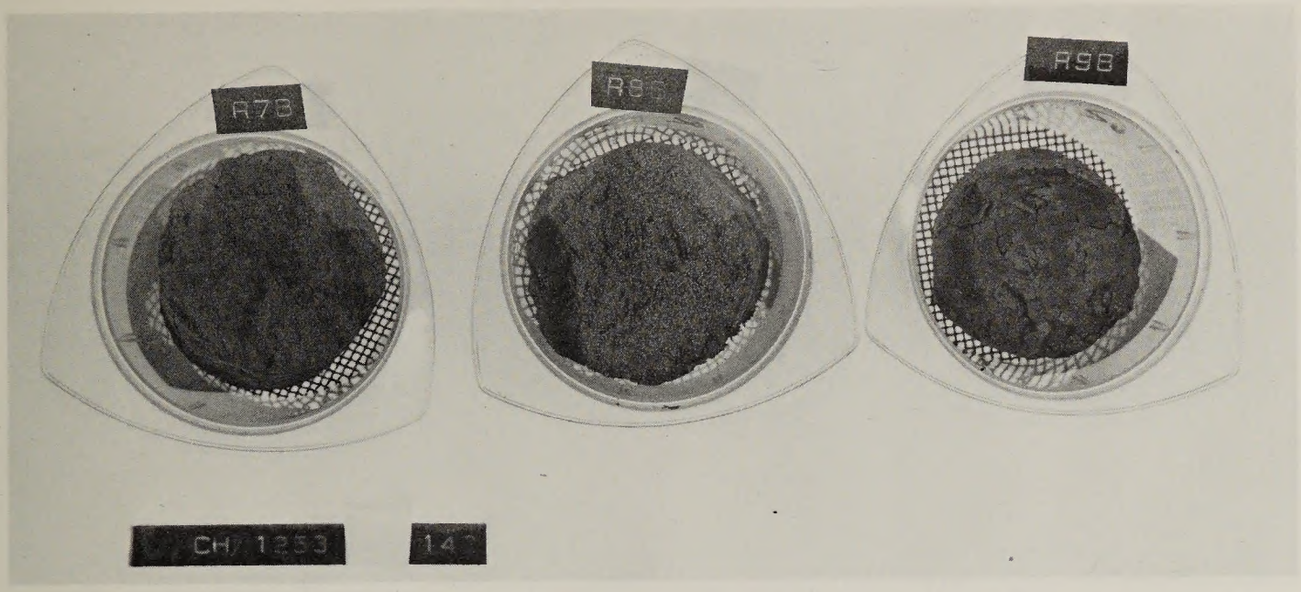


a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Photo 12 - Results of weathering tests for shale samples R-4 and R-5, and sandy siltstone sample R-6 subjected to 10 weeks of outdoor exposure.

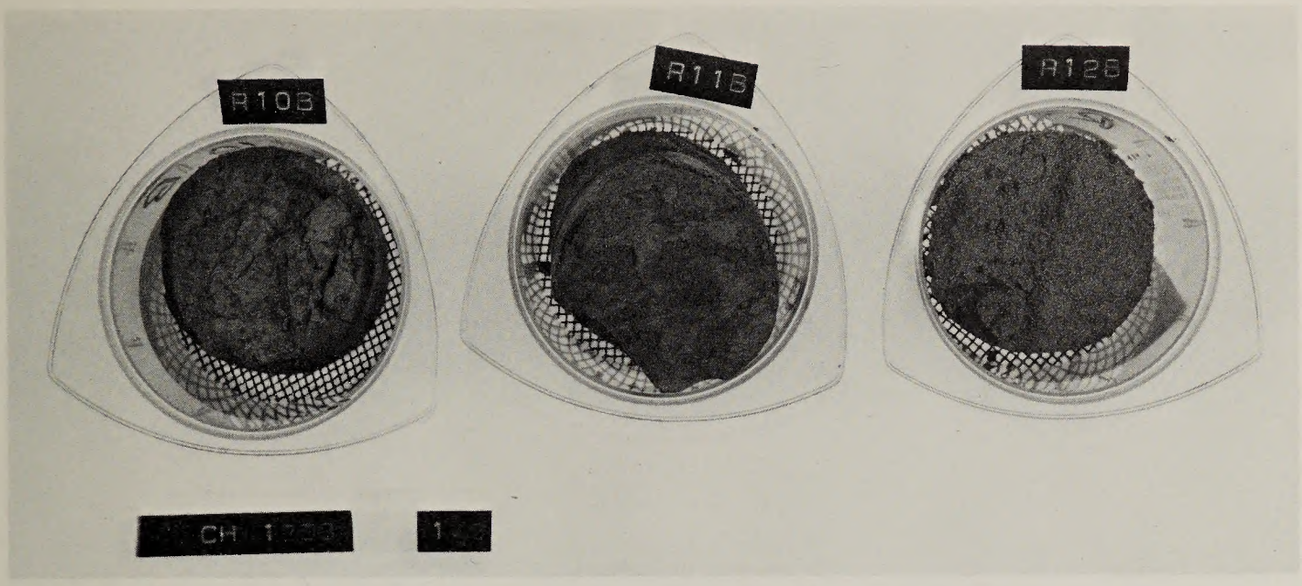


a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Photo 13 - Results of weathering tests for sandy shale sample R-7, clayey sandstone sample R-8, and shale sample R-9 subjected to 10 weeks of outdoor exposure.

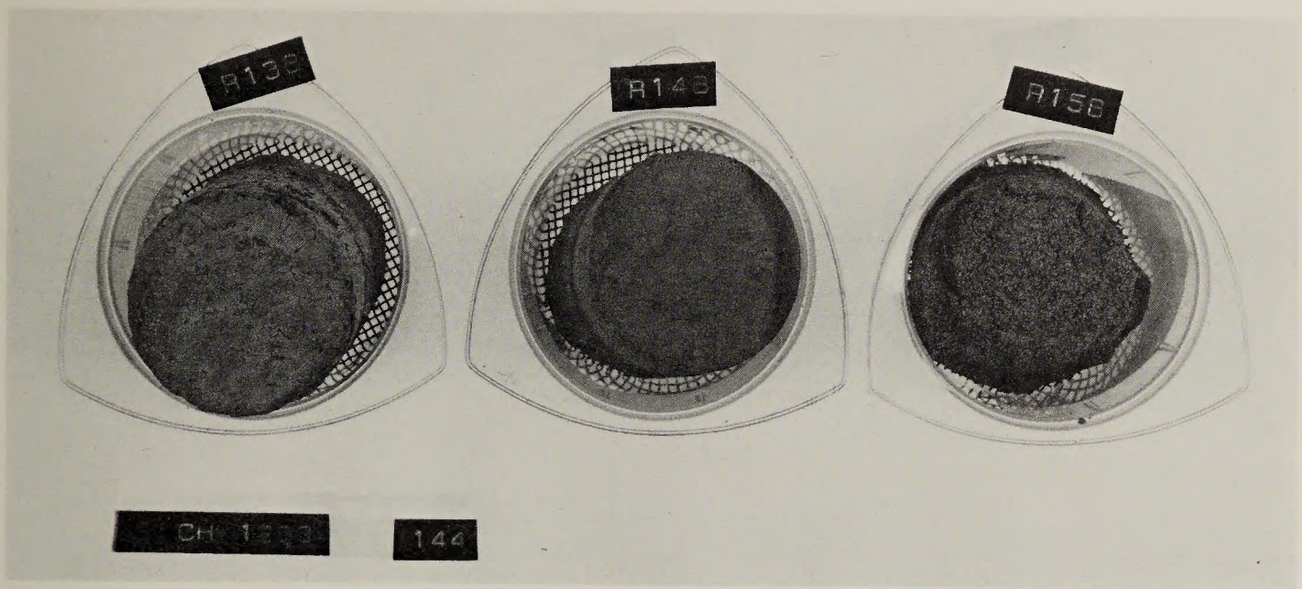


a. Original condition of test specimens.

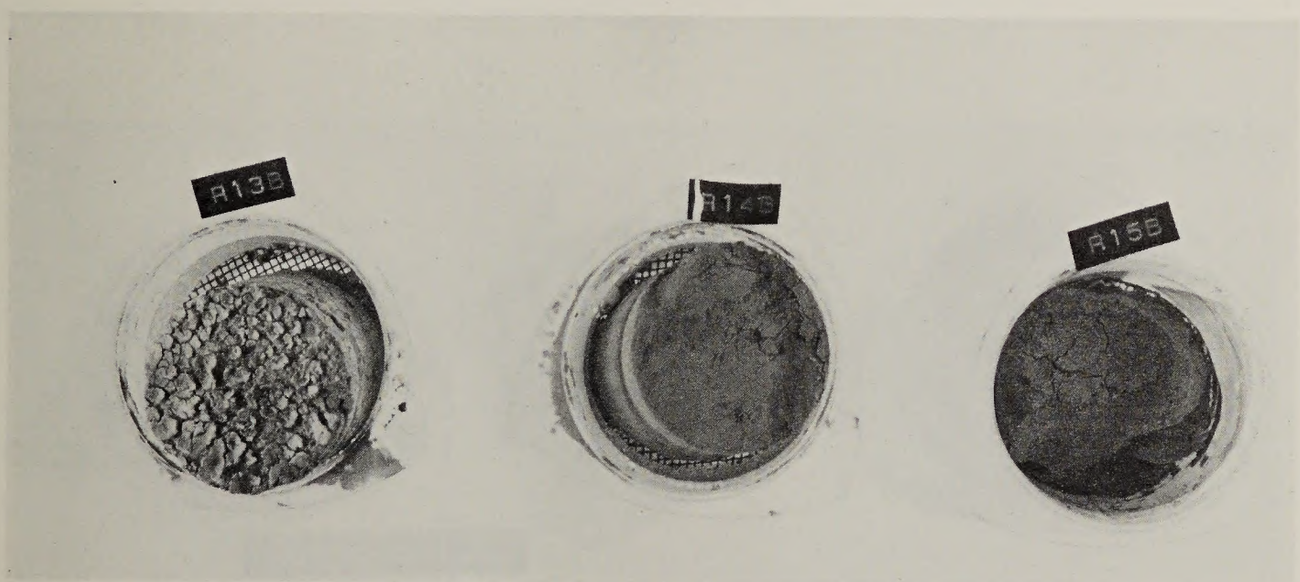


b. Condition of test specimens after weathering.

Photo 14 - Results of weathering tests for shale sample R-10, sandy shale R-11, and clayey sandstone sample R-12 subjected to 10 weeks of outdoor exposure.

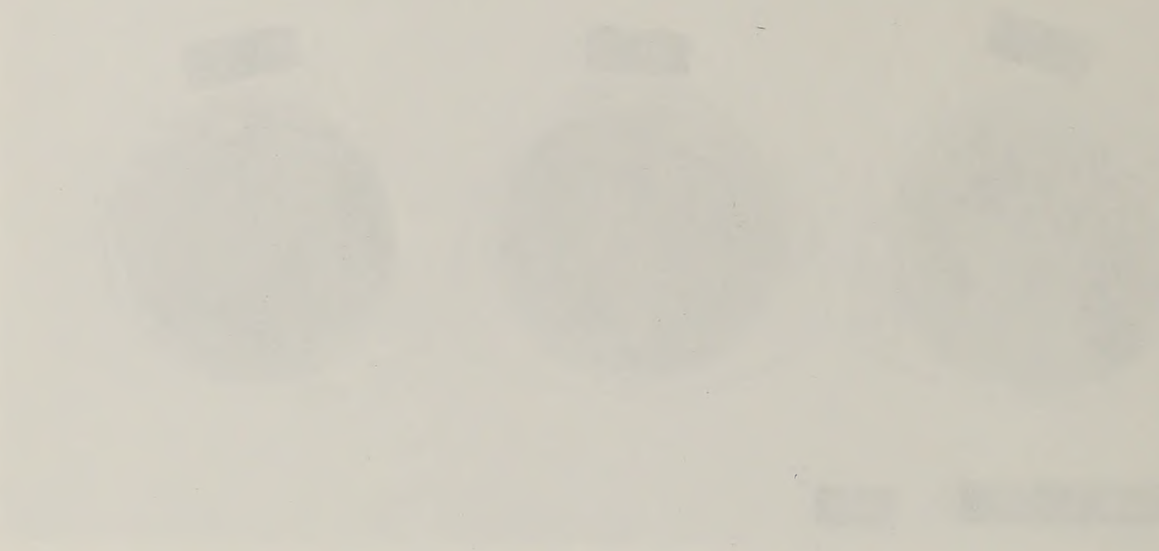


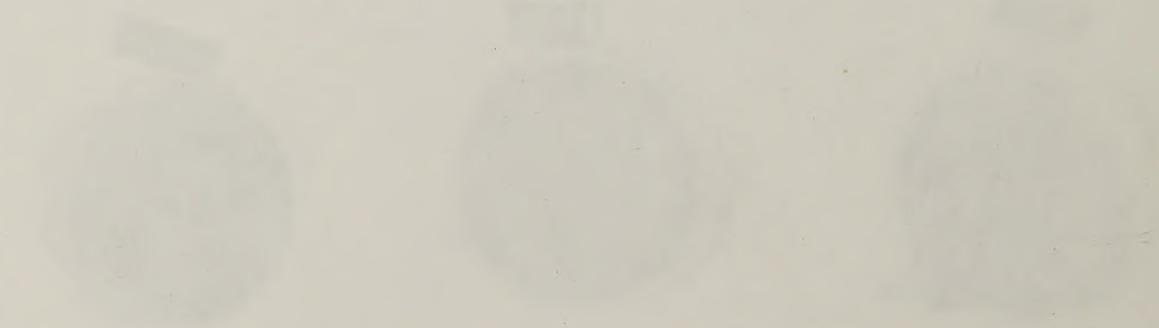
a. Original condition of test specimens.

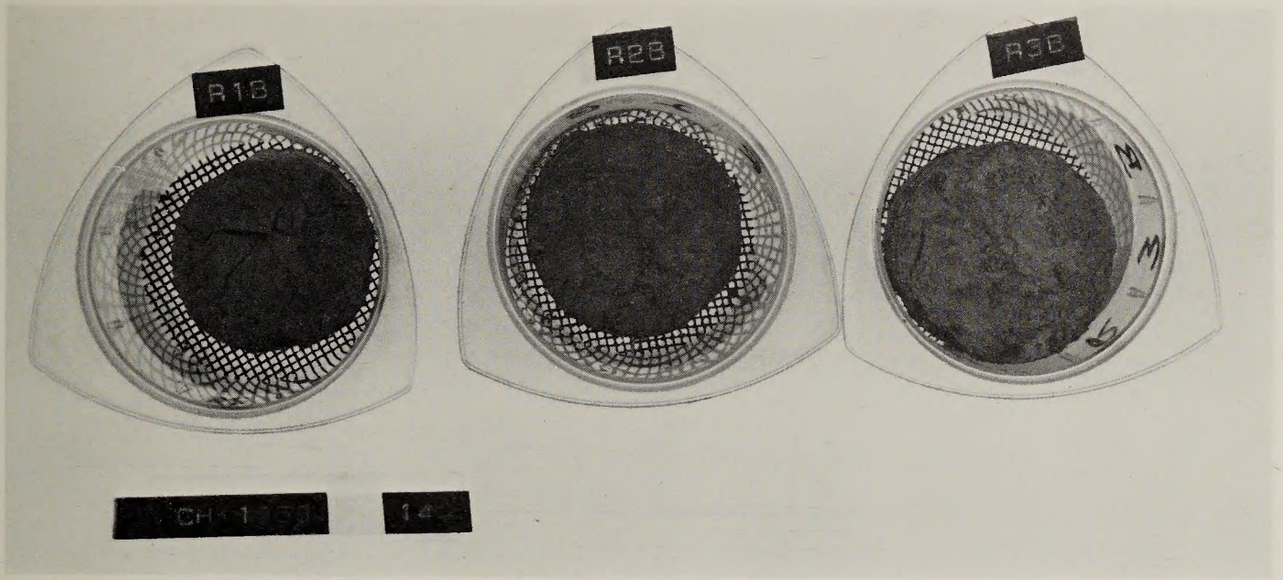


b. Condition of test specimens after weathering.

Photo 15 - Results of weathering tests for shale samples R-13 and R-14, and clayey sandstone sample R-15 subjected to 10 weeks of outdoor exposure.





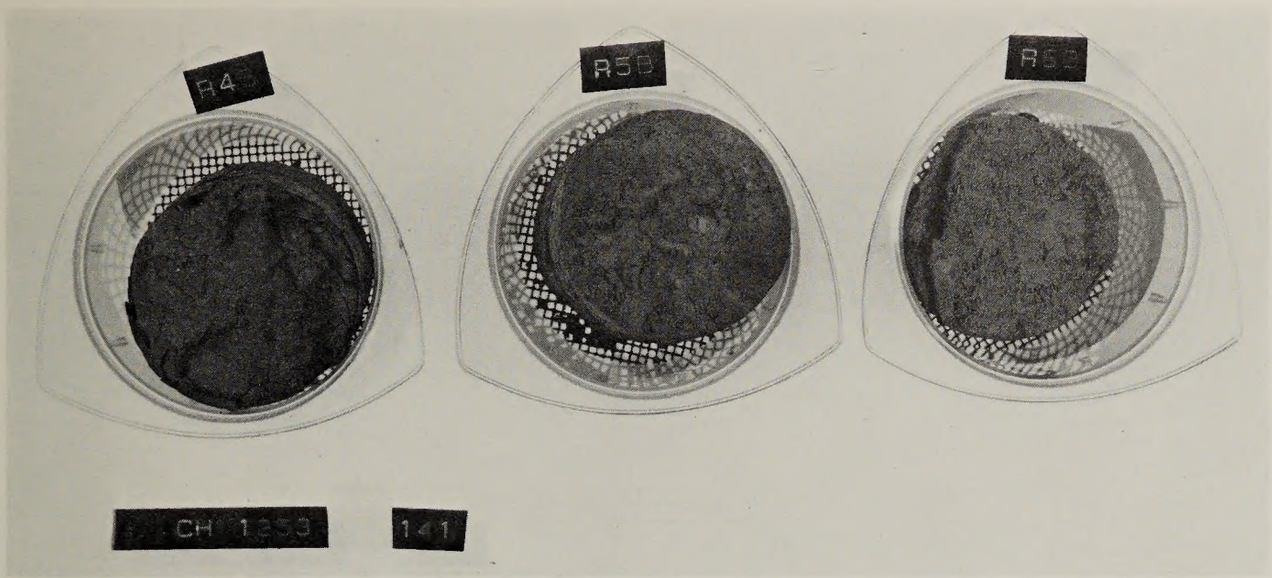


a. Original condition of test specimens.

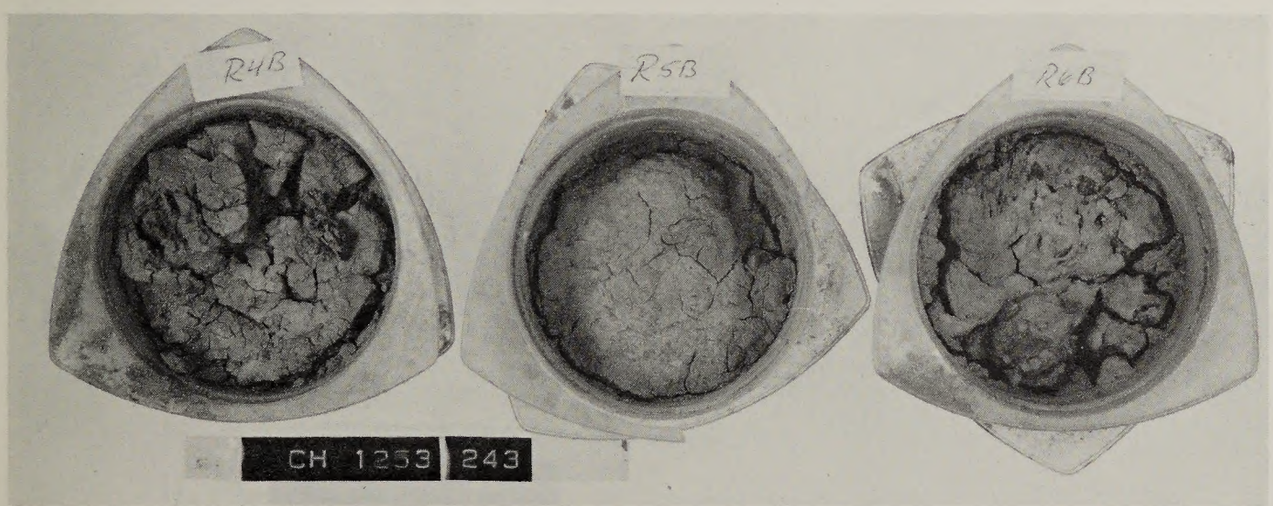


b. Condition of test specimens after weathering.

Photo 16 - Results of weathering tests for shale samples R-1, R-2, and R-3 subjected to 1 year of outdoor exposure.

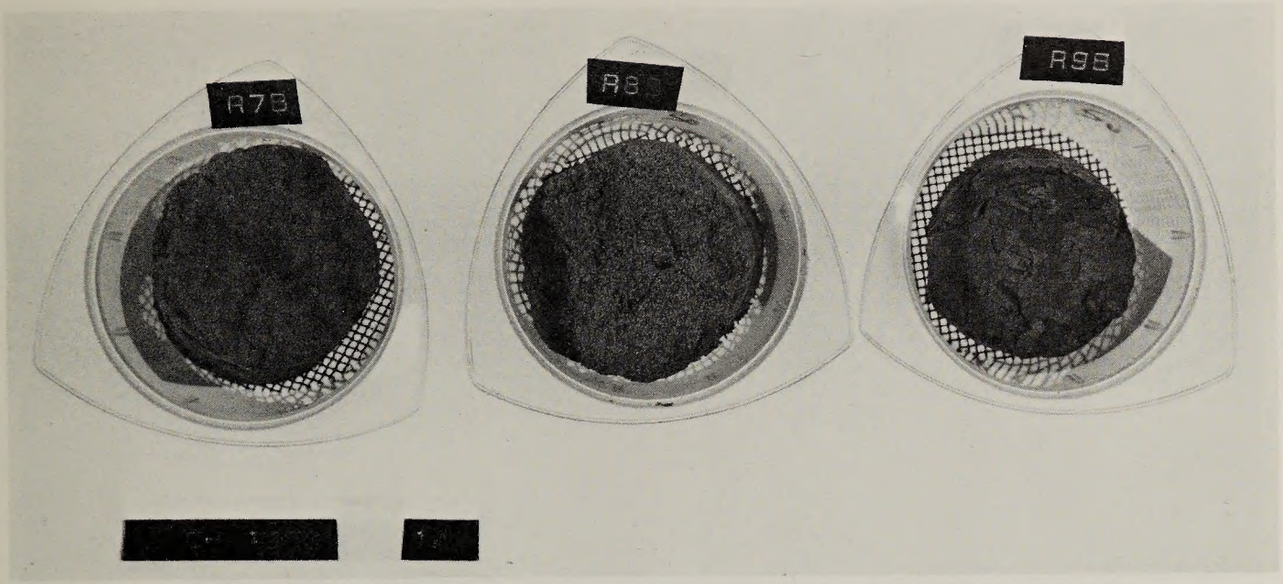


a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Photo 17 - Results of weathering tests for shale samples R-4 and R-5, and sandy siltstone sample R-6 subjected to 1 year of outdoor exposure.

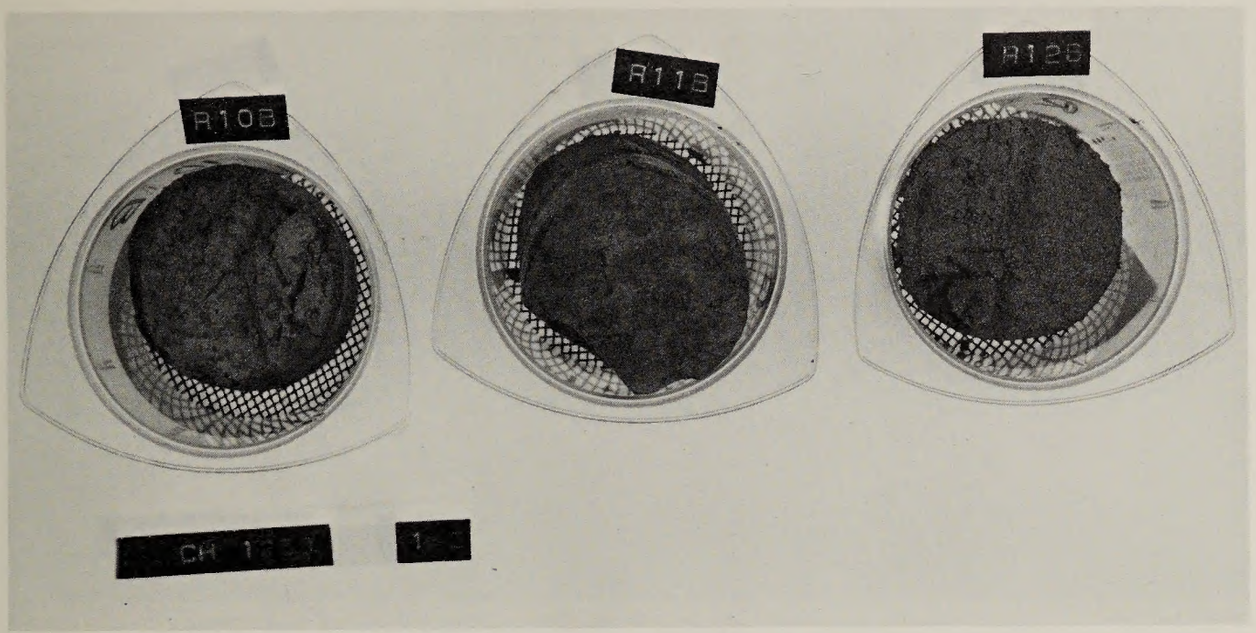


a. Original condition of test specimens.

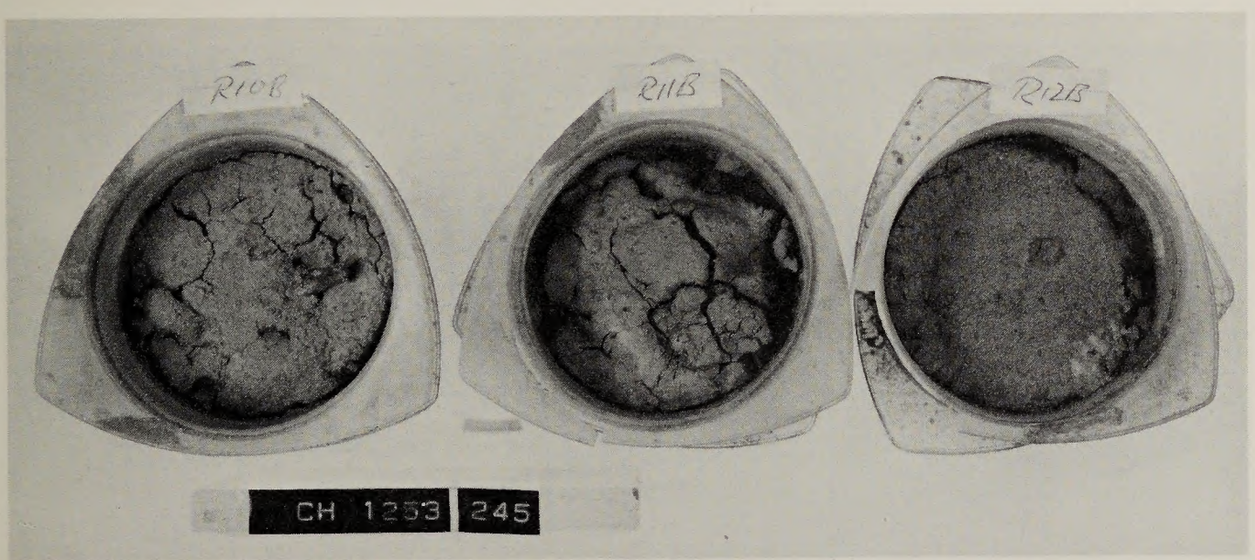


b. Condition of test specimens after weathering.

Photo 18 - Results of weathering tests for sandy shale sample R-7, clayey sandstone sample R-8, and shale sample R-9 subjected to 1 year of outdoor exposure.

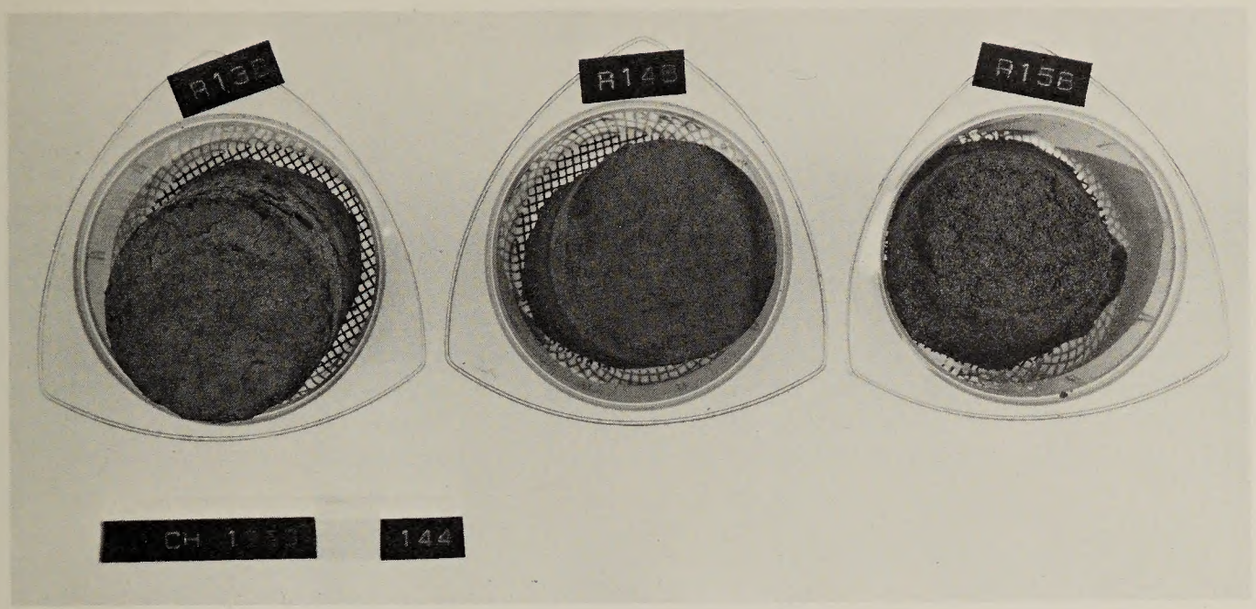


a. Original condition of test specimens.

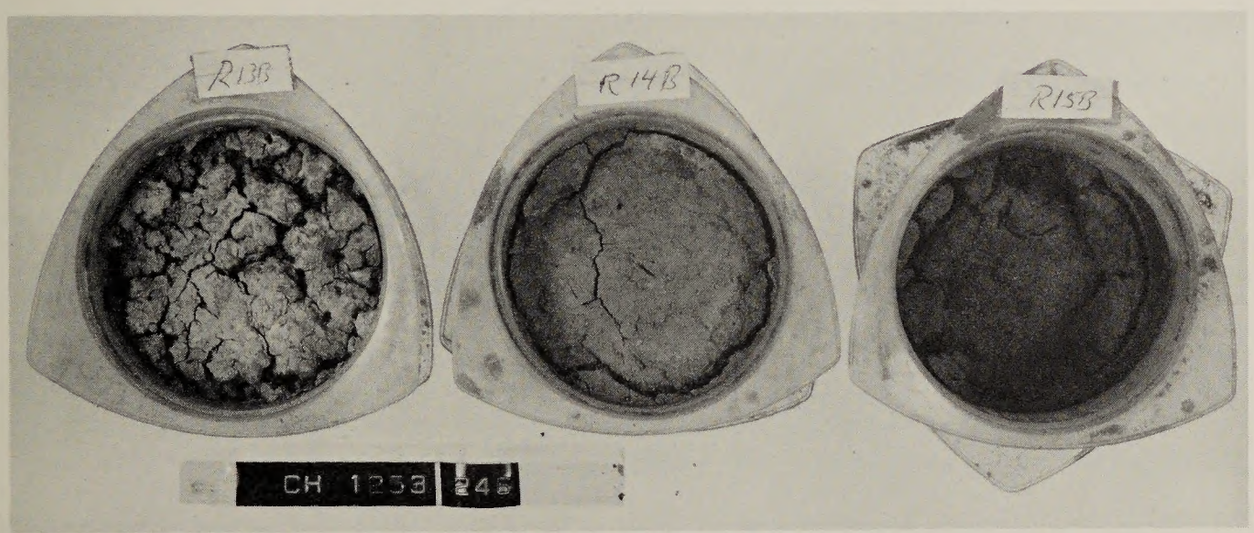


b. Condition of test specimens after weathering.

Photo 19 - Results of weathering tests for shale sample R-10, sandy shale R-11, and clayey sandstone sample R-12 subjected to 1 year of outdoor exposure.



a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Photo 20 - Results of weathering tests for shale samples R-13 and R-14, and clayey sandstone sample R-15 subjected to 1 year of outdoor exposure.

APPENDIX C
COAL RESOURCES

COAL[1/]

Origin

Coal has been defined as "a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and range of impurity (grade) are characteristics of the varieties of coal" (Schopf, 1966, p. 588). Inherent in the definition is the specification that the coal originated as a mixture of organic plant remains and inorganic mineral matter that accumulated in a manner similar to that in which modern-day peat deposits are formed. The peat underwent a long, complex process called "coalification", during which diverse physical and chemical changes occurred as the peat changed to coal and as the coal assumed characteristics by which members of the series are differentiated from each other. The factors that affect the composition of coals have been summarized by Francis (1961, p. 2) as follows:

1) The mode of accumulation and burial of the plant debris forming the deposit.

2) The age of the deposits and their geographical distribution.

3) The structure of the coal-forming plants, particularly details of structure that affect chemical composition or resistance to decay.

4) The chemical composition of the coal-forming debris and its resistance to decay.

5) The nature and intensity of the plant-decaying agencies.

6) The subsequent geological history of the residual products of decay of the plant debris forming the deposits.

These factors, are discussed in greater detail by Moore (1940), Lowry (1945), Tomkeieff (1954), Francis (1961), and Lowry (1963).

Classification

Coals are classified in many ways (Tomkeieff, 1954, p. 9; Moore, 1940, p. 113,; Francis, 1961, p. 361), but the classification by rank, that is, by degree of metamorphism in the progressive series that begins with peat and ends with graphocite (Schopf, 1966), is the most commonly used system. Classification by types of plant materials is commonly used as a descriptive adjunct to rank classification when sufficient megascopic and microscopic information is available, and classification by type and quantity of impurities (grade) is also frequently used when utilization of the coal is being considered. Other categorizations are possible and are commonly employed in discussion of coal resources. Factors such as density of the coal, thickness and areal extent of

1/ Supplement to Coal Resources Section.

individual coal beds, and the thickness of overburden are generally considered.

Rank of Coal

The position of a coal within the metamorphic series, which begins with peat and ends with graphocite, is dependent upon temperature and pressure to which the coal has been subjected and the duration of time of subjection. Because it is, by definition, largely derived from plant material, coal is mostly composed of carbon, hydrogen, and oxygen along with smaller quantities of nitrogen, sulfur, and other elements. The increase in rank of coal as it undergoes progressive metamorphism is indicated by changes in the proportions of the coal constituents; for example, the higher rank coals have more carbon and less hydrogen than the lower rank coals.

Two standardized forms of coal analyses--the proximate analysis and the ultimate analysis--are generally used, although sometimes only the less complicated and less expensive proximate analysis is made. The analyses are described as follows (U.S. Bureau of Mines, 1965, p. 121-122):

> The proximate analysis of coal involves the determination of four constituents: (1) water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases or vapors driven out when coal is heated to certain temperatures; and (4) fixed carbon, the solid or cokelike residue that burns at higher temperatures after volatile matter has been driven off. Ultimate analysis involves the determination of carbon and hydrogen as found in the gaseous products of combustion, the determination of sulfur, nitrogen, and ash in the material as a whole, and the estimation of oxygen by difference.

Most coals are burned to produce heat energy, and so the heat of combustion of the coal is an important property. The heat of combustion (calorific value) is commonly expressed in British thermal units (Btu) per pound: one Btu is the amount of heat required to raise the temperature of 1 pound of water 1 degree fahrenheit (in the metric system, heat of combustion is expressed in kilogram-calories per kilogram). Additional tests are sometimes made, particularly to determine the caking, coking, and other properties, such as tar yield, which affect classification or utilization.

Figure 1 compares, in histogram form, the heat of combustion and moisture, volatile matter, and fixed carbon contents of coals of different ranks.

Various schemes for classifying coals by rank have been proposed and used, but the most commonly employed is that entitled, "Standard specifications for classification of coals by rank," adopted by the American Society for Testing and Materials (1977) (Table 5).

The ASTM classification system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon or volatile matter and the heating value, supplemented by determination of agglomerating (caking) characteristics. As pointed out by the ASTM (1977, p. 216), a standard rank determination cannot be made unless the samples were obtained in accordance

Figure 1

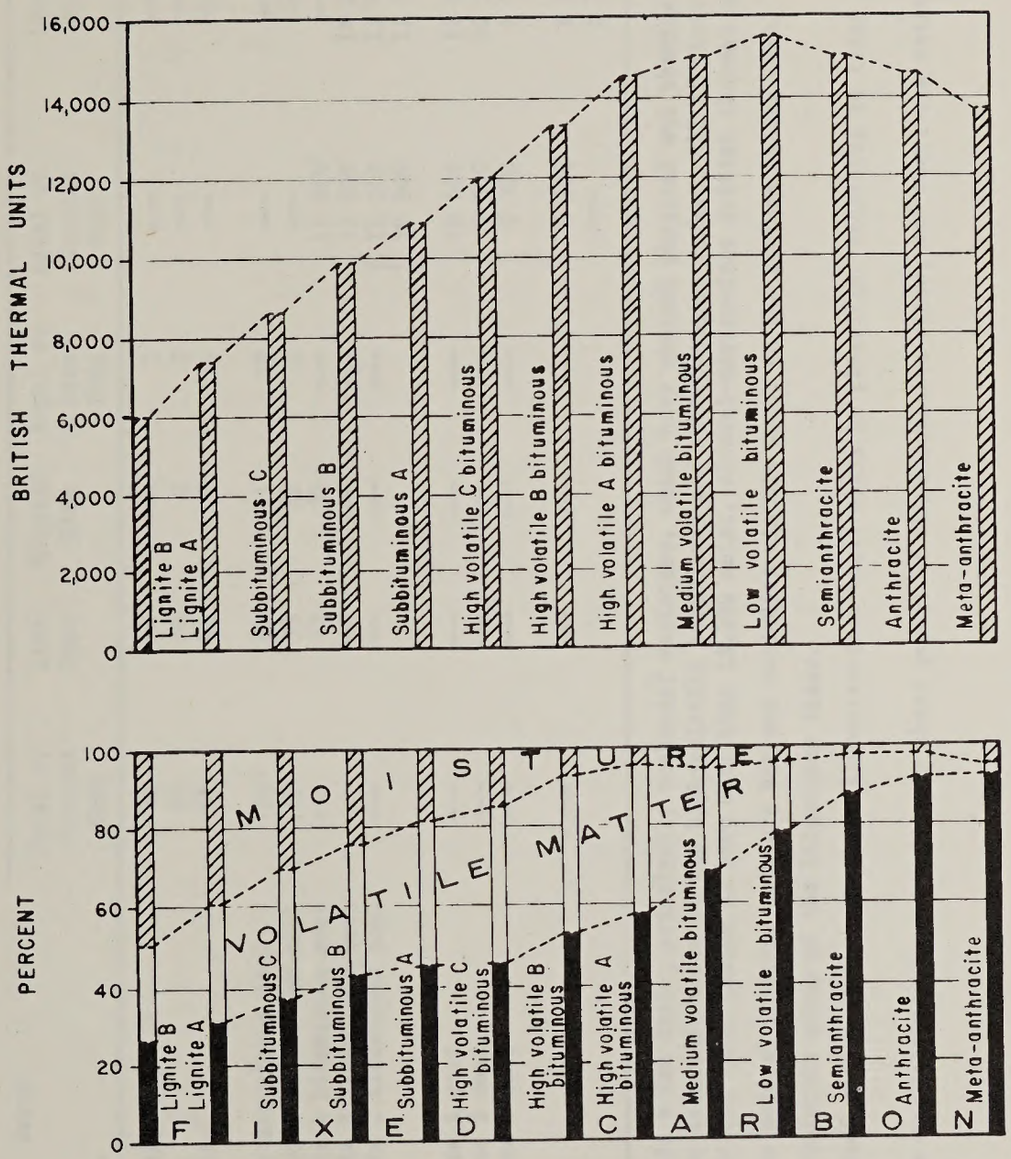


Fig. 1 -- Comparison (on moist, mineral-matter-free basis) of heat values of combustion and proximate analyses of coal of different ranks. (from Averitt, 1975, p. 17)





Table 5 --Classification of coals by rank[1]

[American Society for Testing and Materials Standard D388-66 (Reapproved 1972); 1 Btu equals 0.252 kilogram-calories]

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis)		Volatile Matter Limits, percent (Dry, Mineral Matter-Free Basis)		Calorific Value Limits, Btu per pound (Moist,[2] Mineral-Matter-Free Basis)		Agglomerating Character
		Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less Than	
I. Anthracite	1. Meta-anthracite	98	---	---	2	---	---	nonagglomerating
	2. Anthracite	92	98	2	8	---	---	
	3. Semianthracite[3]	86	92	8	14	---	---	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	---	---	commonly agglomerating[5]
	2. Medium volatile bituminous coal	69	78	22	31	---	---	
	3. High volatile A bituminous coal	---	69	31	---	14 000[4]	---	
	4. High volatile B bituminous coal	---	---	---	---	13 000[4]	14 000	
	5. High volatile C bituminous coal	---	---	---	---	11 500	13 000	
						10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous A coal	---	---	---	---	10 500	11 500	nonagglomerating
	2. Subbituminous B coal	---	---	---	---	9 500	10 500	
	3. Subbituminous C coal	---	---	---	---	8 300	9 500	
IV. Lignitic	1. Lignite A	---	---	---	---	6 300	8 300	
	2. Lignite B					---	6 300	

[1]This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[2]Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[3]If agglomerating, classify in low-volatile group of the bituminous class.

[4]Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[5]It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile C bituminous group.

with standardized sampling procedures (Schopf, 1960). However, nonstandard samples may be used for comparative purposes through determinations designated as "apparent rank." For this study area 19 samples analyzed by the U.S. Department of Energy show heat of combustion values that range from 4570 to 6220 Btu/lb on the as-received basis. Based on these data the apparent rank of the coal ranges from lignite A to lignite B.

Type of Coal

Classification of coals by type--that is, according to the types of plant materials present--takes many forms, such as the "rational analysis" of Francis (1961) or the semicommercial "type" classification commonly used in the coal fields of the eastern United States (U.S. Bureau of Mines, 1965, p. 123). However, most of the type classifications are based on the same, or similar, gross distinctions in plant material as those used by Tomkeieff (1954, Table II and p. 9), who divided the coals into three series: humic coals, humic-sapropelic coals, and sapropelic coals, based upon the nature of the original plant materials. The humic coals are largely composed of the remains of the woody parts of plants and the sapropelic coals are largely composed of the more resistant waxy, fatty, and resinous parts of plants, such as cell walls, spore-coatings, pollen, resin particles, and coals composed mainly of algal material. Most coals fall into the humic series, with some coals being a mixture of humic and sapropelic elements and, therefore, falling into the humic-sapropelic series. The sapropelic series is quantitatively insignificant and when found is commonly regarded as an organic curiosity. In common with most of the U.S. coals, those from the Rattlesnake Butte EMRIA study site fall largely in the humic series.

Grade of Coal

Classification of coal by grade, or quality, is based largely on the content of ash, sulfur, and other constituents that adversely affect utilization.

The ash content of 19 lignite samples from the Rattlesnake Butte study site, on the as-received basis, ranges from 5.5 to 25.9 percent, averaging 10.6 percent; and the sulfur content ranges from 0.3 to 3.0 percent, averaging 1.0 percent (Table 6). For comparison, the ash content of 32 lignite samples from Dunn County, North Dakota (Hatch and Affolter, 1978), ranges from 3.7 to 19.8 percent, averaging 8.4 percent; and the sulfur content ranges from 0.2 to 2.6 percent, averaging 1.1 percent.

Table 8--Estimated identified coal resources of the Heart River (IV) lignite bed under 0-50 feet of overburden, Sentinel Butte Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, Stark, Billings and Dunn Counties, North Dakota as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters; 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

Location	Measured			Indicated			Inferred			Total
	Thickness of coal in feet			Thickness of coal in feet			Thickness of coal in feet			
	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	
T. 140 N., R. 98 W.										
sec. 2	---	0.075	---	---	---	---	---	---	---	0.075
4	---	1.37	---	---	4.42	---	---	0.329	---	6.12
6	0.461	---	1.91	---	2.67	0.179	---	---	---	5.22
8	---	.912	---	---	4.00	.305	---	---	---	5.22
10	---	---	---	---	---	---	---	---	---	---
14	---	---	---	---	---	---	---	---	---	---
18	---	---	1.43	---	---	2.02	---	---	---	3.45
20	---	.642	---	---	3.86	.263	---	---	.401	5.17
22	---	.041	---	---	---	2.53	---	---	1.34	3.91
26	---	.085	---	---	3.56	---	---	.520	---	4.16
28	---	---	---	---	1.03	.212	---	2.36	---	3.60
30	---	---	---	---	---	---	---	---	---	---
32	---	.804	---	---	1.21	---	---	---	---	2.01
34	---	.628	---	---	.124	---	---	---	---	.752
Township total	0.461	4.56	3.34	---	20.9	5.51	---	3.21	1.74	39.7
T. 140 N., R. 99 W.										
sec. 2	---	0.050	---	---	3.38	---	---	3.14	---	6.57
10	---	.962	---	---	4.01	---	---	.470	---	5.44
12	---	---	---	---	0.107	---	---	.095	---	0.202
14	---	---	---	---	1.50	---	---	1.06	---	2.56
22	0.418	---	---	0.493	---	---	---	---	---	.911
24	---	---	---	---	---	---	---	---	---	---
26	---	---	0.133	.165	2.28	---	0.904	1.23	---	4.71
34	---	---	1.15	---	---	1.85	---	---	2.95	5.95
Township total	0.418	1.01	1.28	0.658	11.3	1.85	0.904	6.00	2.95	26.4
T. 141 N., R. 97 W.										
sec. 32	---	---	---	---	---	1.26	---	---	2.67	3.93
Township total	---	---	---	---	---	1.26	---	---	2.67	3.93
T. 141 N., R. 98 W.										
sec. 26	---	---	0.198	---	---	0.594	---	---	---	0.792
32	---	---	---	---	4.17	.809	---	0.283	3.21	8.47
34	---	0.702	---	---	.544	1.48	---	---	---	2.73
Township total	---	0.702	0.198	---	4.71	2.88	---	0.283	3.21	12.0
Total	0.879	6.27	4.82	0.658	36.9	11.5	0.904	9.49	10.6	82.0

Table 9 --Estimated identified coal resources of the Heart River (IV) lignite bed under 50-100 feet of overburden, Sentinel Butte Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, Stark, Billings and Dunn Counties, North Dakota as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters; 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

Location	Measured			Indicated			Inferred			Total
	Thickness of coal in feet			Thickness of coal in feet			Thickness of coal in feet			
	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	
T. 140 N., R. 98 W.										
sec. 2	---	2.61	0.260	---	0.123	7.77	---	---	0.648	11.4
4	---	---	---	---	0.009	---	---	3.25	---	3.26
6	---	1.01	.546	---	2.58	---	---	---	---	4.14
8	---	---	---	---	.915	---	---	.499	---	1.41
10	---	---	---	---	1.22	---	---	1.60	---	2.82
14	---	.685	.031	---	2.70	---	---	---	---	3.42
18	---	---	.073	---	---	---	---	---	---	.073
20	---	.223	.609	---	.134	.577	---	---	---	1.54
22	---	.477	---	---	---	2.57	---	---	1.14	4.19
26	---	.368	1.44	---	3.42	---	---	---	---	5.23
28	---	---	---	---	.504	---	---	1.18	---	1.68
30	---	---	---	---	---	---	---	---	---	---
32	---	.011	---	---	---	---	---	---	---	.011
34	---	---	---	---	---	---	---	---	---	---
Township total	---	5.38	2.96	---	11.6	10.9	---	6.53	1.79	39.2
T. 140 N., R. 99 W.										
sec. 2	---	0.409	---	---	0.612	---	---	0.169	---	1.19
10	---	.418	---	---	2.85	---	---	.044	---	3.31
12	---	---	---	---	---	---	---	---	---	---
14	---	---	---	---	---	---	---	.045	---	0.045
22	0.144	---	---	0.368	.421	---	---	---	---	.933
24	---	---	---	---	---	---	---	---	---	---
26	---	---	---	.233	.024	---	0.157	---	---	.414
34	---	---	---	---	---	---	---	---	2.28	2.28
Township total	0.144	0.827	---	0.601	3.91	---	0.157	0.258	2.28	8.18
T. 141 N., R. 97 W.										
sec. 32	---	---	---	---	---	1.57	---	---	0.393	1.96
Township total	---	---	---	---	---	1.57	---	---	0.393	1.96
T. 141 N., R. 98 W.										
sec. 26	---	---	0.292	---	---	---	---	---	---	0.292
32	---	0.853	---	---	0.622	---	---	---	---	1.47
34	---	---	---	---	---	---	---	---	---	---
Township total	---	0.853	0.292	---	0.622	---	---	---	---	1.77
Total	0.144	7.06	3.25	0.601	16.1	12.5	0.157	6.79	4.46	51.1

Table 10 -Estimated identified coal resources of the Heart River (IV) lignite bed under >100 feet of overburden, Sentinel Butte Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, Stark, Billings and Dunn Counties, North Dakota as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters; 1 short ton = 0.907 metric ton. a, includes .050 million tons with >150′ overburden; b, includes 0.30 million tons with >150′ overburden; numbers are rounded to three significant figures.]

Location	Measured			Indicated			Inferred			Total
	Thickness of coal in feet			Thickness of coal in feet			Thickness of coal in feet			
	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	
T. 140 N., R. 98 W.										
sec. 2	---	0.892	---	---	0.269	0.552	---	---	0.718	2.43
4	---	---	---	---	---	---	---	0.125	---	0.125
6	---	---	---	---	---	---	---	---	---	---
8	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	.367	---	---	[a]1.22	---	1.59
14	---	.787	---	---	[b].876	---	---	---	---	1.66
18	---	---	---	---	---	---	---	---	---	---
20	---	---	---	---	---	---	---	---	---	---
22	---	---	---	---	---	.179	---	---	---	.179
26	---	---	---	---	---	---	---	---	---	---
28	---	---	---	---	.035	---	---	---	---	.035
30	---	---	---	---	---	---	---	---	---	---
32	---	---	---	---	---	---	---	---	---	---
34	---	---	---	---	---	---	---	---	---	---
Township total	---	1.68	---	---	1.55	.731	---	1.34	0.718	6.02
T. 140 N., R. 99 W.										
sec. 2	---	---	---	---	---	---	---	---	---	---
10	---	0.322	---	---	---	---	---	---	---	0.322
12	---	---	---	---	---	---	---	---	---	---
14	---	---	---	---	---	---	---	---	---	---
22	---	---	---	.009	---	---	---	---	---	.009
24	---	---	---	---	---	---	---	---	---	---
26	---	---	---	.030	---	---	---	---	---	.030
34	---	---	---	---	---	---	---	---	---	---
Township total	---	0.322	---	0.039	---	---	---	---	---	0.361
T. 141 N., R. 97 W.										
sec. 32	---	---	---	---	---	---	---	---	---	---
Township total	---	---	---	---	---	---	---	---	---	---
T. 141 N., R. 98 W.										
sec. 26	---	---	---	---	---	---	---	---	---	---
32	---	0.024	---	---	---	---	---	---	---	0.024
34	---	---	---	---	---	---	---	---	---	---
Township total	---	0.024	---	---	---	---	---	---	---	0.024
Total	---	2.03	---	0.039	1.55	0.731	---	1.34	0.718	6.41

Table 11 --Summary of estimated identified coal resources of the Heart River (1V) lignite bed, Sentinel Butte Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters. 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

	T. 140 N. R. 98 W.	T. 140 N. R. 99 W.	T. 141 N. R. 97 W.	T. 141 N. R. 98 W.	Total
Coal bed 2 1/2 to 5 feet thick					
Measured resources	0.461	0.562	---	---	1.02
Indicated resources	---	1.30	---	---	1.30
Inferred resources	---	1.061	---	---	1.06
Total	0.461	2.92	---	---	3.38
Coal bed 5-10 feet thick					
Measured resources	11.6	2.16	---	1.58	15.3
Indicated resources	34.0	15.2	---	5.33	54.5
Inferred resources	11.1	6.26	---	.283	17.6
Total	56.7	23.6	---	7.19	87.5
Coal bed >10 feet thick					
Measured resources	6.30	1.28	---	0.490	8.07
Indicated resources	17.1	1.85	2.83	2.88	24.7
Inferred resources	4.25	5.23	3.06	3.21	15.7
Total	27.6	8.36	5.89	6.58	48.5
Total identified resources	84.8	34.9	5.89	13.8	139.

Table 12 --Estimated identified coal resources of the Fryburg (VIII) lignite bed under 0-50 feet of overburden, Sentinel Butte Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, Stark, Billings and Dunn Counties, North Dakota as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters; 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

Location	Measured			Indicated			Inferred			
	Thickness of coal in feet			Thickness of coal in feet			Thickness of coal in feet			
	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	Total
T. 140 N., R. 98 W.										
sec. 2	---	---	---	---	---	---	---	---	---	---
4	---	---	---	---	---	---	---	---	---	---
6	---	---	---	---	---	---	---	---	---	---
8	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---
14	---	---	---	---	---	---	---	---	---	---
18	0.022	---	---	1.11	---	---	0.110	---	---	1.24
20	---	---	---	---	---	---	---	---	---	---
22	---	---	---	---	---	---	---	---	---	---
26	---	---	---	---	---	---	---	---	---	---
28	---	---	0.340	---	---	---	---	---	---	0.340
30	---	0.175	---	---	---	3.22	---	---	1.53	4.93
32	---	---	---	---	---	.406	---	---	---	.406
34	---	---	---	---	1.60	---	---	0.103	---	1.70
Subtotal	0.022	0.175	0.340	1.11	1.60	3.63	0.110	0.103	1.53	8.62
T. 140 N., R. 99 W.										
sec. 2	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---
12	---	---	---	0.153	---	---	0.009	---	---	0.162
14	0.083	---	---	0.588	---	---	---	---	---	.671
22	---	---	---	---	---	---	---	---	---	---
24	.379	.892	---	---	4.07	---	---	0.120	---	5.46
26	---	---	---	---	---	---	---	---	---	---
34	---	---	---	---	---	---	---	---	---	---
Subtotal	0.462	0.892	---	0.741	4.07	---	0.009	0.120	---	6.29
T. 141 N., R. 97 W.										
sec. 32	---	---	---	---	---	---	---	---	---	---
Subtotal	---	---	---	---	---	---	---	---	---	---
T. 141 N., R. 98 W.										
sec. 26	---	---	---	---	---	---	---	---	---	---
32	---	---	---	---	---	---	---	---	---	---
34	---	---	---	---	---	---	---	---	---	---
Subtotal	---	---	---	---	---	---	---	---	---	---
Total	0.484	1.07	0.340	1.85	5.67	3.63	0.119	0.223	1.53	14.9

Table 13.--Estimated identified coal resources of the Fryburg (VIII) lignite bed under 50-100 feet of overburden, Sentinel Butte Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, Stark, Billings and Dunn Counties, North Dakota as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters; 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

Location	Measured			Indicated			Inferred			Total
	Thickness of coal in feet			Thickness of coal in feet			Thickness of coal in feet			
	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	
T. 140 N., R. 98 W.										
sec. 2	---	---	---	---	---	---	---	---	---	---
4	---	---	---	---	---	---	---	---	---	---
6	---	---	---	---	---	---	---	---	---	---
8	0.014	---	---	1.07	---	---	---	---	---	1.08
10	---	---	---	---	---	---	---	---	---	---
14	---	---	---	---	---	---	---	---	---	---
18	.765	---	---	1.06	---	---	---	---	---	1.82
20	---	0.059	---	---	3.46	1.01	---	---	0.631	5.16
22	---	---	---	---	---	1.49	---	---	.380	1.870
26	---	---	---	---	0.106	1.23	---	0.337	---	1.67
28	---	---	1.28	---	---	3.49	---	---	---	4.77
30	---	---	---	---	---	0.291	---	---	1.68	1.97
32	---	---	2.30	---	---	4.51	---	---	---	6.80
34	---	---	1.79	---	1.25	0.561	---	---	2.56	6.16
Subtotal	0.779	0.059	5.37	2.13	4.82	12.6	---	0.337	5.25	31.3
T. 140 N., R. 99 W.										
sec. 2	---	---	---	0.231	---	---	0.081	---	---	0.312
10	---	---	---	---	---	---	.071	---	---	.071
12	---	---	---	.358	---	---	---	---	---	.358
14	0.081	---	---	.441	---	---	---	---	---	.522
22	.539	---	---	---	1.60	---	---	---	---	2.14
24	.013	---	---	.535	.370	---	---	0.124	---	1.04
26	---	---	0.017	---	---	2.02	---	.279	2.08	4.40
34	---	---	.089	---	---	1.249	---	---	0.751	2.09
Subtotal	0.633	---	0.106	1.56	1.97	3.27	0.152	0.403	2.83	10.9
T. 141 N., R. 97 W.										
sec. 32	---	---	---	---	---	---	---	---	---	---
Subtotal	---	---	---	---	---	---	---	---	---	---
T. 141 N., R. 97 W.										
sec. 26	---	---	---	---	---	---	---	---	---	---
32	---	---	---	0.154	---	---	1.32	---	---	1.47
34	0.031	---	---	.198	---	---	---	---	---	0.229
Subtotal	0.031	---	---	0.352	---	---	1.32	---	---	1.70
Total	1.44	0.059	5.48	4.04	6.79	15.9	1.47	0.740	8.08	44.0

Table 14 --Estimated identified coal resources of the Fryburg (VIII) lignite bed under 100-150 feet of overburden, Sentinel Butte Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, Stark, Billings and Dunn Counties, North Dakota as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters; 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

Location	Measured			Indicated			Inferred			
	Thickness of coal in feet			Thickness of coal in feet			Thickness of coal in feet			
	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	Total
T. 140 N., R. 98 W.										
sec. 2	---	0.887	---	---	0.543	0.787	---	---	---	2.22
4	---	.784	---	---	3.15	---	---	0.407	---	4.34
6	---	.376	---	0.519	---	---	0.086	---	---	0.981
8	0.500	---	---	.056	1.56	---	---	.153	---	2.27
10	---	---	---	---	0.043	.522	---	.337	0.054	.956
14	---	.459	0.279	---	---	3.65	---	---	---	4.39
18	.082	---	---	---	---	---	---	---	---	.082
20	---	---	1.62	---	1.44	1.15	---	---	---	4.21
22	---	---	.656	---	---	5.56	---	---	1.75	7.97
26	---	---	.564	---	2.50	3.17	---	.298	---	6.53
28	---	---	.127	---	---	3.00	---	---	.958	4.09
30	---	---	---	---	---	---	---	---	---	---
32	---	---	.997	---	---	.829	---	---	---	1.83
34	---	.006	.085	---	---	---	---	---	---	.091
Subtotal	0.582	2.51	4.33	0.575	9.24	18.7	0.086	1.19	2.76	40.0
T. 140 N., R. 99 W.										
sec. 2	0.020	---	---	0.861	---	---	0.139	---	---	1.02
10	---	---	---	.016	---	---	.030	---	---	0.046
12	---	---	---	.008	---	---	---	---	---	.008
14	---	---	---	---	---	---	---	---	---	---
22	.116	0.361	---	.044	1.75	---	---	---	---	2.27
24	---	---	---	---	---	---	---	---	---	---
26	---	---	0.128	---	.412	1.30	---	1.01	0.701	3.55
34	---	---	1.08	---	---	1.97	---	---	2.60	5.65
Subtotal	0.136	0.361	1.21	0.929	2.163	3.27	0.169	1.01	3.30	12.5
T. 141 N., R. 97 W.										
sec. 32	---	---	---	---	0.284	---	---	0.305	---	0.589
Subtotal	---	---	---	---	0.284	---	---	0.305	---	0.589
T. 141 N., R. 98 W.										
sec. 26	0.134	---	---	0.200	---	---	---	---	---	0.334
32	---	---	---	.992	---	---	1.44	---	---	2.43
34	.233	---	---	.582	---	---	0.106	---	---	.921
Subtotal	0.367	---	---	1.77	---	---	1.55	---	---	3.69
Total	1.08	2.87	5.54	3.27	11.7	22.0	1.80	2.51	6.06	56.8

Table 15 --Estimated identified coal resources of the Fryburg (VIII) lignite bed under 150-200 feet of overburden, Sentinel Butte Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, Stark, Billings and Dunn Counties, North Dakota as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters; 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

Location	Measured			Indicated			Inferred			Total
	Thickness of coal in feet			Thickness of coal in feet			Thickness of coal in feet			
	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	
T. 140 N., R. 98 W.										
sec. 2	---	1.45	---	---	3.96	1.22	---	0.537	0.557	7.72
4	---	0.311	---	---	1.60	---	---	4.05	---	5.96
6	0.223	.084	---	1.84	---	---	0.522	---	---	2.67
8	---	---	---	---	0.165	---	---	.263	---	0.428
10	---	---	---	---	1.48	---	---	2.06	.024	3.56
14	---	.541	0.326	---	---	1.16	---	---	---	2.03
18	---	---	---	---	---	---	---	---	---	---
20	---	---	.238	---	.071	---	---	---	---	.309
22	---	---	.129	---	---	.776	---	---	.632	1.54
26	---	---	1.46	---	.303	.538	---	---	---	2.30
28	---	---	---	---	---	1.73	---	---	.136	1.87
30	---	---	---	---	---	---	---	---	---	---
32	---	---	---	---	---	---	---	---	---	---
34	---	---	---	---	---	---	---	---	---	---
Subtotal	0.223	2.39	2.15	1.84	7.58	5.42	0.522	6.91	1.35	28.4
T. 140 N., R. 99 W.										
sec. 2	0.010	---	---	0.265	---	---	0.015	---	---	0.290
10	---	---	---	---	---	---	---	---	---	---
12	---	---	---	---	---	---	---	---	---	---
14	---	---	---	---	---	---	---	---	---	---
22	---	0.065	---	---	0.566	---	---	---	---	.631
24	---	---	---	---	---	---	---	---	---	---
26	---	---	---	---	.602	---	---	---	0.037	.639
34	---	---	---	---	---	---	---	---	2.54	2.54
Subtotal	0.010	0.065	---	0.265	1.17	---	.015	---	2.58	4.10
T. 141 N., R. 97 W.										
sec. 32	---	---	---	---	2.06	---	---	1.27	---	3.33
Subtotal	---	---	---	---	2.06	---	---	1.27	---	3.33
T. 141 N., R. 98 W.										
sec. 26	---	---	---	---	---	---	---	---	---	---
32	0.032	---	---	0.421	---	---	0.021	---	---	0.474
34	---	---	---	---	---	---	.018	---	---	.018
Subtotal	0.032	---	---	0.421	---	---	0.039	---	---	0.492
Total	0.265	2.45	2.15	2.53	10.8	5.42	0.576	8.18	3.93	36.3

Table 16 --Estimated identified coal resources of the Fryburg (VIII) lignite bed under >200 feet of overburden, Sentinel Butte Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, Stark, Billings and Dunn Counties, North Dakota as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters; 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

Location	Measured			Indicated			Inferred			Total
	Thickness of coal in feet			Thickness of coal in feet			Thickness of coal in feet			
	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	
T. 140 N., R. 98 W.										
sec. 2	---	0.554	---	---	0.114	---	---	0.137	---	0.805
4	---	---	---	---	---	---	---	.082	---	.082
6	0.027	---	---	0.037	---	---	---	---	---	.064
8	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	.652	---	.652
14	---	---	---	---	---	---	---	---	---	---
18	---	---	---	---	---	---	---	---	---	---
20	---	---	---	---	---	---	---	---	---	---
22	---	---	---	---	---	---	---	---	---	---
26	---	---	---	---	---	---	---	---	---	---
28	---	---	---	---	---	---	---	---	---	---
30	---	---	---	---	---	---	---	---	---	---
32	---	---	---	---	---	---	---	---	---	---
34	---	---	---	---	---	---	---	---	---	---
Subtotal	0.027	0.554	---	0.037	0.114	---	---	0.871	---	1.60
T. 140 N., R. 99 W.										
sec. 2	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---
12	---	---	---	---	---	---	---	---	---	---
14	---	---	---	---	---	---	---	---	---	---
22	---	---	---	---	---	---	---	---	---	---
24	---	---	---	---	---	---	---	---	---	---
26	---	---	---	---	0.024	---	---	---	---	0.024
34	---	---	---	---	---	---	---	---	---	---
Subtotal	---	---	---	---	0.024	---	---	---	---	0.024
T. 141 N., R. 97 W										
sec. 32	---	---	---	---	0.070	---	---	---	---	0.070
Subtotal	---	---	---	---	0.070	---	---	---	---	0.070
T. 141 N., R. 98 W.										
sec. 26	---	---	---	---	---	---	---	---	---	---
32	---	---	---	---	---	---	---	---	---	---
34	---	---	---	---	---	---	---	---	---	---
Subtotal	---	---	---	---	---	---	---	---	---	---
Total	0.027	0.554	---	0.037	0.208	---	---	0.871	---	1.70

Table 17 --Summary of estimated identified coal resources of the Fryburg (VIII) lignite bed, Sentinel Butte Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters. 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

	T. 140 N. R. 98 W.	T. 140 N. R. 99 W.	T. 141 N. R. 97 W.	T. 141 N. R. 98 W.	Total
Coal bed 2 1/2 to 5 feet thick					
Measured resources	1.63	1.24	---	0.430	3.30
Indicated resources	5.69	3.50	---	2.54	11.7
Inferred resources	.718	.345	---	2.91	3.97
Total	8.04	5.09	---	5.88	19.0
Coal bed 5-10 feet thick					
Measured resources	5.69	1.32	---	---	7.01
Indicated resources	23.4	9.39	2.41	---	35.2
Inferred resources	9.41	1.53	1.57	---	12.5
Total	38.5	12.2	3.98	---	54.7
Coal bed >10 feet thick					
Measured resources	12.2	1.32	---	---	13.5
Indicated resources	40.3	6.54	---	---	46.8
Inferred resources	10.9	8.71	---	---	19.6
Total	63.4	16.6	---	---	79.9
Total identified resources	110.	33.9	3.98	5.88	154.

Table 18 --Estimated identified coal resources of the HT Butte (XIII) lignite bed under >200 feet of overburden, Tongue River Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, Stark, Billings and Dunn Counties, North Dakota as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters; 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

Location	Measured			Indicated			Inferred			Total
	Thickness of coal in feet			Thickness of coal in feet			Thickness of coal in feet			
	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	
T. 140 N., R. 98 W.										
sec. 2	---	---	---	---	---	---	4.17	---	---	4.17
4	---	0.207	---	---	2.18	---	---	5.34	---	7.72
6	---	.043	---	---	2.91	---	---	8.83	---	11.8
8	---	1.15	---	---	2.35	2.30	---	1.19	1.13	8.12
10	---	---	---	---	---	---	2.71	---	---	2.71
14	0.014	---	---	0.596	---	---	0.848	---	---	1.46
18	---	---	---	---	---	---	---	2.51	9.39	11.9
20	---	---	1.38	---	---	8.50	---	---	4.16	14.0
22	---	---	---	---	2.86	---	---	2.45	---	5.31
26	---	---	---	---	---	---	1.13	---	---	1.13
28	---	.590	0.788	---	5.09	0.036	---	1.38	---	7.88
30	---	.115	---	---	2.80	---	---	2.05	---	4.97
32	---	---	---	---	2.89	---	---	2.23	---	5.12
34	---	.326	---	---	1.14	---	---	3.71	---	5.18
Subtotal	0.014	2.43	2.17	0.596	22.2	10.8	8.86	29.7	14.7	91.5
T. 140 N., R. 99 W.										
sec. 2	---	---	---	---	---	---	---	8.31	---	8.31
10	---	0.554	---	---	3.44	---	---	4.23	---	8.22
12	---	---	---	---	---	---	---	7.73	---	7.73
14	---	.371	---	---	3.46	---	---	5.81	---	9.64
22	---	.561	---	---	3.41	---	---	2.26	---	6.23
24	---	.894	---	---	4.53	---	---	3.98	---	9.40
26	---	---	---	---	---	---	---	6.21	---	6.21
34	---	---	---	---	---	---	---	4.63	---	4.63
Subtotal	---	2.38	---	---	14.8	---	---	43.2	---	60.4
T. 141 N., R. 97 W.										
sec. 32	---	---	---	0.506	---	---	1.62	---	---	2.13
Subtotal	---	---	---	0.506	---	---	1.62	---	---	2.13
T. 141 N., R. 98 W.										
26	---	---	---	---	0.703	---	---	0.194	---	0.897
32	---	---	---	---	.621	---	---	7.30	---	7.92
34	---	---	---	---	0.813	---	---	3.10	---	3.91
Subtotal	---	---	---	---	2.14	---	---	10.6	---	12.7
Total	0.014	4.81	2.17	1.10	39.1	10.8	10.5	83.5	14.7	167.

Table 19.--Estimated identified coal resources of the HT Butte (XIII) rider lignite bed under >200 feet of overburden, Tongue River Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, Stark, Billings and Dunn Counties, North Dakota as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters; 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

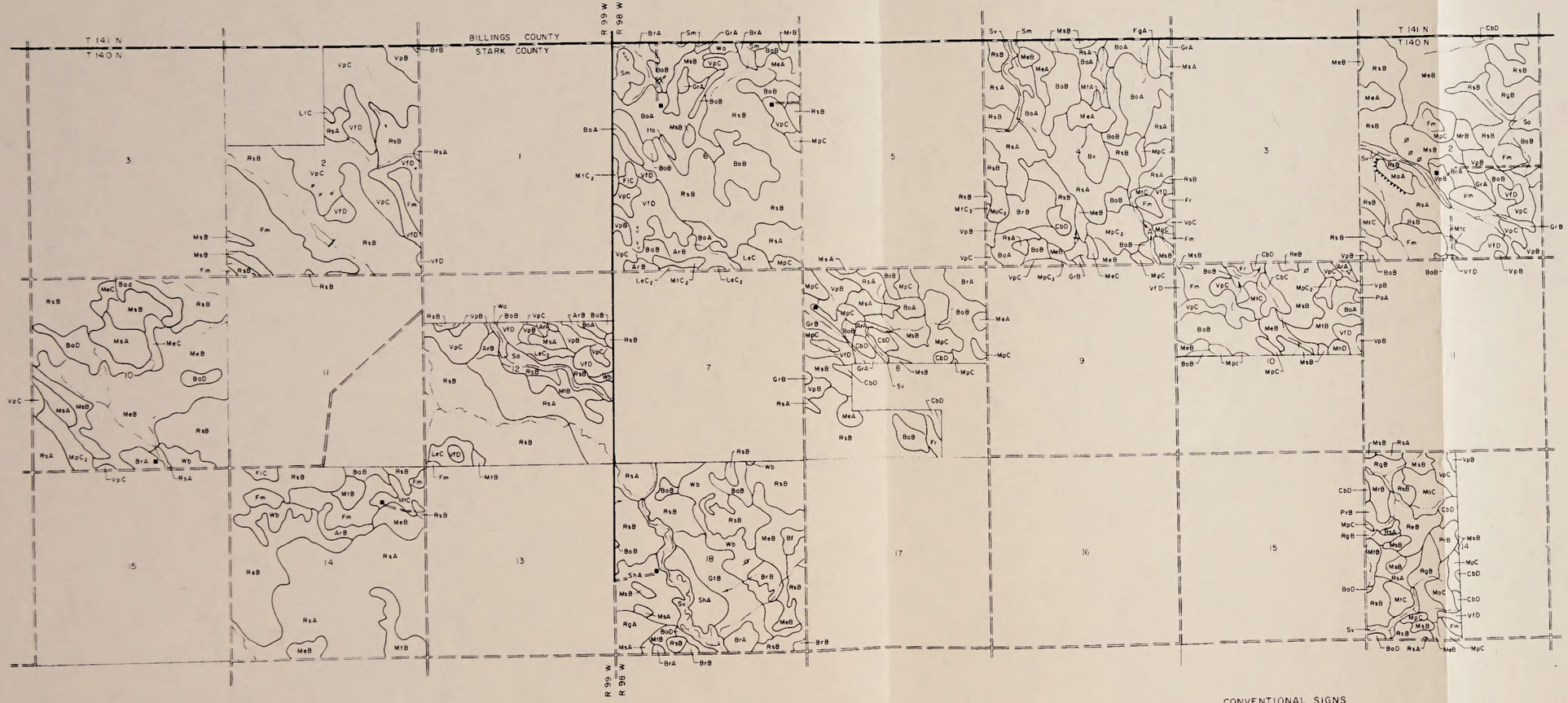
Location	Measured			Indicated			Inferred			Total
	Thickness of coal in feet			Thickness of coal in feet			Thickness of coal in feet			
	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	2 1/2-5	5-10	>10	
T. 140 N., R. 98 W.										
sec. 2	---	---	---	---	---	---	2.03	---	---	2.03
4	0.145	---	---	1.86	---	---	3.37	---	---	5.38
6	---	---	---	---	---	---	---	---	---	---
8	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	2.41	---	---	2.41
14	.015	---	---	1.36	---	---	1.20	---	---	2.58
18	---	---	---	---	---	---	---	---	---	---
20	---	---	---	---	---	---	---	---	---	---
22	---	---	---	1.78	---	---	0.687	---	---	2.47
26	---	---	---	---	---	---	5.27	---	---	5.27
28	.317	---	---	1.23	---	---	.155	---	---	1.70
30	---	---	---	---	---	---	---	---	---	---
32	---	---	---	---	---	---	---	---	---	---
34	---	---	---	---	---	---	---	---	---	---
Subtotal	0.477	---	---	6.23	---	---	15.1	---	---	21.8
T. 140 N., R. 99 W.										
sec. 2	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---
12	---	---	---	---	---	---	---	---	---	---
14	---	---	---	---	---	---	---	---	---	---
22	---	---	---	---	---	---	---	---	---	---
24	---	---	---	---	---	---	---	---	---	---
26	---	---	---	---	---	---	---	---	---	---
34	---	---	---	---	---	---	---	---	---	---
Subtotal	---	---	---	---	---	---	---	---	---	---
T. 141 N., R. 97 W.										
sec. 32	---	---	---	---	---	---	---	---	---	---
Subtotal	---	---	---	---	---	---	---	---	---	---
T. 141 N., R. 98 W.										
sec. 26	---	---	---	0.502	---	---	0.060	---	---	0.562
32	---	---	---	---	---	---	---	---	---	---
34	---	---	---	.616	---	---	1.31	---	---	1.93
Subtotal	---	---	---	1.12	---	---	1.37	---	---	2.49
Total	0.477	---	---	7.35	---	---	16.5	---	---	24.3

Table 20 --Summary of estimated identified lignite resources of the HT Butte (XIII) and HT Butte rider lignite beds, Tongue River Member, Fort Union Formation, Rattlesnake Butte EMRIA study site, as of August 1, 1980

[Leaders (---) indicate not present. In millions of short tons. 1 foot = 0.305 meters. 1 short ton = 0.907 metric ton; numbers are rounded to three significant figures.]

	T. 140 N. R. 98 W.	T. 140 N. R. 99 W.	T. 141 N. R. 97 W.		T. 141 N. R. 98 W.	Total
Coal bed 2 1/2 to 5 feet thick						
Measured resources	0.491	---	---	---	0.491	
Indicated resources	6.83	---	0.506		1.12	8.46
Inferred resources	24.0	---	1.62	1.37	27.0	
Total	31.3	---	2.13	2.49	35.9	
Coal bed 5-10 feet thick						
Measured resources	2.43	2.38	---	---	4.81	
Indicated resources	22.2	14.8	---	2.14	39.1	
Inferred resources	29.7	43.2	---	10.6	83.5	
Total	54.3	60.4	---	12.7	127.	
Coal bed >10 feet thick						
Measured resources	2.17	---	---	---	2.17	
Indicated resources	10.8	---	---	---	10.8	
Inferred resources	14.7	---	---	---	14.7	
Total	27.7	---	---	---	27.7	
Total identified resources	113.	60.4	2.13	15.2	191.	

APPENDIX D
OVERBURDEN - SOIL AND BEDROCK



SOIL MAPPING UNIT

SYMBOL	DESCRIPTION
ArA	Arnegard loam, level
ArB	Arnegard loam, gently sloping
BaB	Bainville and Midway soils, undulating
BaD	Bainville and Midway soils, steep
Bf	Bainville – Shale outcrop complex
Bk	Beckton complex
BoA	Belfield – Rhoades loams, level
BoB	Belfield – Rhoades loams, gently sloping
BrA	Belfield – Rhoades silty clay loams, level
BrB	Belfield – Rhoades silty clay loams, gently sloping
CbC	Chama – Bainville looms, sloping
CbD	Chama – Bainville looms, strongly sloping
FaB	Farland silt loam, gently sloping
FgA	Farland, Arnegard, and Grail silt looms, level
FlC	Flasher sandy loam, sloping
Fm	Flasher complex
Fr	Flasher – rock outcrop complex
GrA	Grail silty clay loam, level
GrB	Grail silty clay loam, gently sloping
GtB	Grail – Rhoades silty clay looms, gently sloping
Ho	Hoven soils
LeC	Lefor fine sandy loam, sloping
LeC_2	Lefor fine sandy loam, sloping, eroded
LlC	Linen – Flasher loamy fine sands, rolling
MoA	Manning loam, level
MeA	Moreau silty clay, level
MeB	Moreau silty clay, gently sloping
MeC	Moreau silty clay, sloping
MgD	Moreau – Midway silty clays, strongly sloping
MnD	Morton – Bainville complex, strongly sloping
MoC	Morton – Chama clay looms, sloping
MpC	Morton – Chama silt looms, sloping
MpC_2	Morton – Chama silt looms, sloping, eroded
MrB	Morton and Farland clay looms, gently sloping
MsB	Morton and Farland silt looms, gently sloping
MtA	Morton – Rhoades looms, level
MtB	Morton – Rhoades looms, gently sloping
MtC	Morton – Rhoades looms, sloping
MtC_2	Morton – Rhoades looms, sloping, eroded
PoA	Porshall fine sandy loam, level
PrA	Promise silty clay, level
PrB	Promise silty clay, gently sloping
ReA	Regent silty clay loam, level
ReB	Regent silty clay loam, gently sloping
RgA	Regent – Moreau silty clay loams, level
RgB	Regent – Moreau silty clay loams, gently sloping
RgC	Regent – Moreau silty clay loams, sloping
RsA	Rhoades and Belfield soils, level
RsB	Rhoades and Belfield soils, gently sloping
Sa	Saline alluvial land
Sg	Savage silty clay loam
Sm	Searing loam
Sv	Straw and Havre soils, channeled
ShA	Savage – Rhoades silty clay loams, level
StA	Straw loam, level
VfD	Vebar – Flasher fine sandy looms, strongly sloping
VpB	Vebar – Porshall fine sandy loams, undulating
VpC	Vebar – Porshall fine sandy loams, sloping
Wo	Wet alluvial land
Wb	Wiboux soils

Sections 2,10,12 & 14, T 140 N, R 99 W.
Sections 2,4,6,8,10,14,18,T 140 N., R 98 W

CONVENTIONAL SIGNS

WORKS AND STRUCTURES

HIGHWAYS AND ROADS
- Dual (Interstate)
- Good Motor
- Poor Motor

BUILDINGS

MINES AND QUARRIES

PITS, GRAVEL OR OTHER

MINE DUMP

DAMS

BOUNDARIES

- County

DRAINAGE

STREAMS
- Perennial
- Intermittent

LAKES AND PONDS
- Perennial
- Drainage ends

SOIL SURVEY DATA

- Soil boundary and symbol
- Stones
- Rock outcrop
- Gumbo or scabby spot
- Areas of alkali and salts

NOTE

Source used for this map, Soil Conservation Service report, "Soil Survey of Stark County, North Dakota" dated 1968.

1:20,000

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

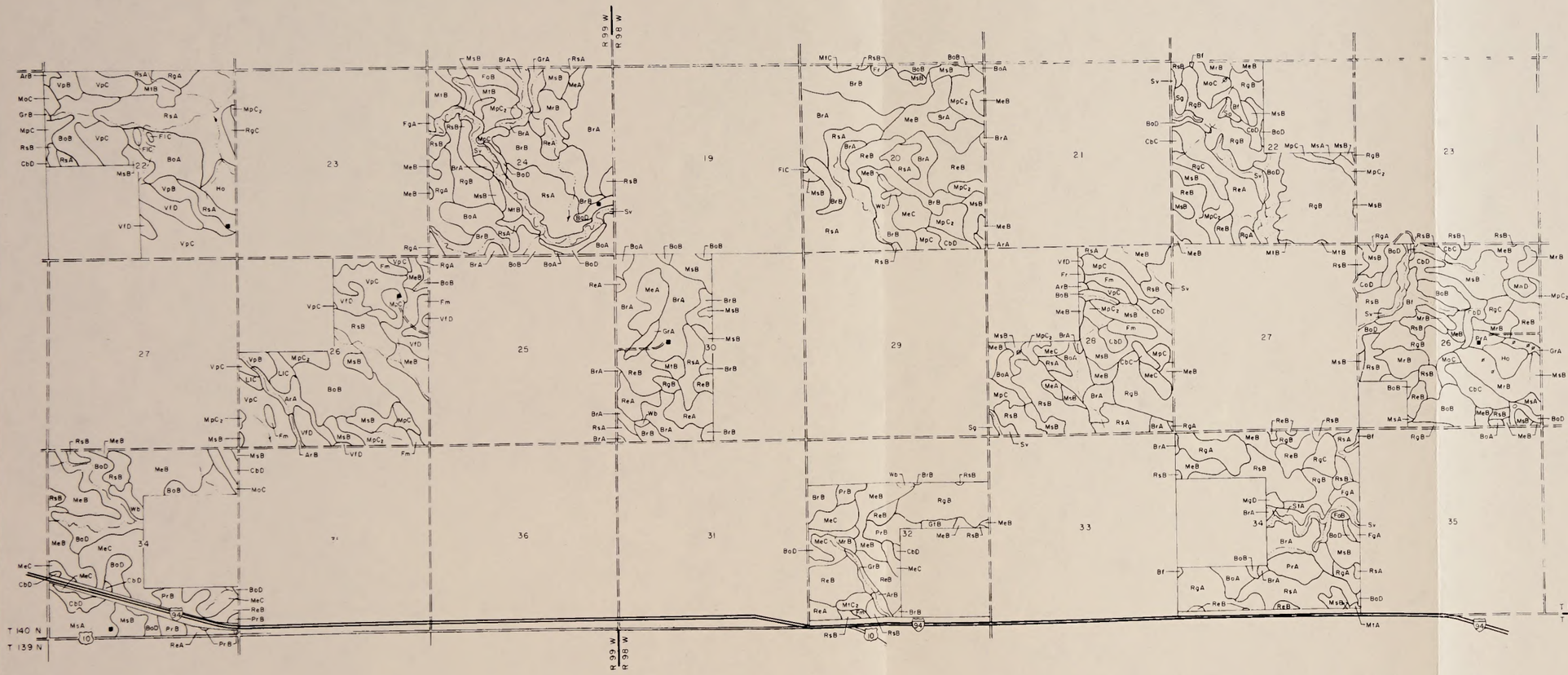
DICKINSON COALFIELD–NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SOIL INVENTORY MAP

DESIGNED G. WESTMAN — FIELD APPROVAL
DRAWN ALLSOP–VETTER — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA JUNE, 1981
SHEET 1 OF 2

1305-600-299



NOTE
For EXPLANATION see Sheet 1 of 2, Dwg No 1305-600-299

1 20,000

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

DICKINSON COALFIELD - NORTH DAKOTA
RATTLESNAKE BUTTE STUDY AREA

SOIL INVENTORY MAP

DESIGNED L. WESTMAN FIELD APPROVAL
DRAWN ALLYOP-VETTER TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA JUNE, 1981
SHEET 2 OF 2

1305-600-300

7-2003A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Rattlesnake Butte
Location. Sec. 10 Twp. 140 N. Ronge 98 W.
1400'E., 400'S., of NW. corner
Climate: Semi-Arid
Land Use: Cultivated

Relief: Complex, Gently rolling
Elevation: 2690
Slope: Aspect: North
Vegetation: Small Grain
Erosion: Slight

Stoniness: None
Droinage: Excessive
Ground Woter: None
Land Form: Residual

Porent Materiol: Soft sandstone
Soil Series: Vebar
Soil Classification: Co. loamy, mixed
Typic Haploborolls
Profile Description By: T. Ficchtl Dote: 8/79
Correlated By: G. Muckel 5/79

Point Site No. 7

LAB NO.	DEPTH (M) (~~Cm.~~)	PROFILE DESCRIPTION
12,298		
T-1137	0-.3	A_p (AB) 0-.30 meters, dark grayish brown (10YR 5/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; moderate, medium blocky structure seperating to weak, coarse, crumb structure; slightly hard dry, very friable moist, slightly sticky, nonplastic wet; plentiful, fine roots, noncalcareous; abrupt boundary.
12,299		
T-1138	.3-.76	C_{ca} .30-.76 meters, light grayish brown (10YR 6/2) very fine sandy loam, dark gray (10YR 4/1) moist; weak, coarse, blocky structure; slightly hard dry, very friable moist, slightly sticky, nonplastic wet; few, fine roots violently calcareous; abrupt boundary.
12,300		
T-1139	.76-1.3	C_2 .76-1.3 meters, light brownish gray (10YR 6/2) soft sandstone, grayish brown (10YR 5/2) moist; massive structure; soft dry, loose moist, nonsticky, nonplastic wet; strongly calcareous; gradual boundary.
12,301		
T-1140	1.3-1.9	C_3 1.3-1.9 meters, light gray (10YR 7/2) soft sandstone, grayish brown (10YR 5/2) moist; massive structure; soft dry, loose moist, nonsticky, nonplastic wet; noncalcareous; diffuse boundary.
12,302		
T-1141	1.9-3.0	C_{41} 1.9-2.5 meters, light brownish gray (10YR 6/2) soft sandstone, grayish brown (10YR 5/2) moist; massive structure; soft dry, loose moist, nonsticky, nonplastic wet; noncalcareous; diffuse boundary.
		C_{42} 2.5-3.0 meters, light brownish gray (10YR 6/2) soft sandstone, grayish brown (10YR 5/2) moist; massive structure; soft dry, loose moist, nonsticky, nonplastic wet; noncalcareous.

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		12,298	12,299	12,300	12,301	12,302
DEPTH	(m)	0-.3	.3-.76	.76-1.3	1.3-1.9	1.9-3.0
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0mm)	2.0		0.0	0.0	0.0
Coarse Sand	(1.0-0.5mm)	2.1		0.5	0.3	0.4
Medium Sand	(0.5-0.25mm)	2.2		1.2	0.8	1.1
Fine Sand	(0.25-0.10mm)	23.4		31.3	16.8	51.0
Very Fine Sand	(0.10-0.05mm)	22.4		37.9	48.9	23.7
Total Sand	(2.0-0.05mm)	52.1	48.2	70.9	66.8	76.2
Silt	(0.05-0.002mm)	33.9	23.2	14.1	20.8	11.7
Clay	(<0.002mm)	14.0	28.6	15.0	12.4	12.1
TEXTURAL CLASS (LAB)		VFSL	SCL	VFSL	VFSL	FSL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(cm/hr)					
6th hr		0.37	0.39	1.22	1.30	1.42
24th hr		0.41	0.33	1.54	1.65	1.57
SETTLING VOLUME	(ml)	23	23	24	23	31
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		11.2	10.6	9.9	9.8	6.7
SOIL REACTION-pH						
Paste						
1:5 H_2O		8.5	8.6	8.9	9.2	9.4
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	-0.6	-0.6	-0.2	+0.7	-0.2
SATURATION EXTRACT						
Saturation Percentage		53.7	51.8	51.9	59.3	66.8
EC_e @ 25°C	(mmhos/cm)	0.5	0.4	0.4	0.5	0.4
Ca^{++}	(me/l)	4.68	2.02	0.74	0.39	0.25
Mg^{++}	(me/l)	0.86	1.66	2.45	1.42	0.50
Na^{+}	(me/l)	0.21	0.23	1.41	3.23	3.92
K^{+}	(me/l)	0.17	0.13	0.16	0.16	0.12
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	4.65	3.26	3.97	3.90	3.83
Cl^{-}	(me/l)	0.09	0.07	0.09	0.09	0.08
SO_4^{-}	(me/l)	1.08	0.37	0.52	0.97	0.47
NO_3^{-}	(me/l)	0.01	0.12	0.17	0.18	0.06
SAR	(me/l)	0.1	0.2	1.1	3.4	6.4
Na	(me/100g)	0.01	0.01	0.07	0.19	0.26
Ca+Mg	(me/100g)	0.30	0.19	0.17	0.10	0.05
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	0.22	0.19	0.17	0.18	0.18
Ca+Mg	(me/l)	1.97	1.67	1.21	0.76	1.33
EXCHANGEABLE SODIUM	(percent)	0.9	0.5	2.1	4.6	7.3
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	17.2	15.2	13.2	11.7	10.3
NaOAc@pH 8.2						
BORON	(mg/l)					

Remarks: It is assumed clay percentage in the .3 to .76 meter lab sample contains approximately 10% carbonate clay.

Table 21

GPO 833-796

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: Rattlesnake Butte
Location. Sec. 8 Twp. 140 N. Range 98 W.
700'E., 200'S., of NW. corner
Climate: Semi-Arid
Land Use: Cultivated

Relief: Simple, gently sloping
Elevation: 2560
Slope: Aspect: South
Vegetation: Small Grain
Erosion: Slight

Stoniness: None
Drainage: Moderate
Ground Water: None
Land Form: Residual

Parent Material: Soft shale
Soil Series: Grail-like
Soil Classification: fine, Montmorillonitic
Pachic Argiborolls
Profile Description By: T. Fiechtl Date: 8/78
Correlated By: C. Muckel 5/79

Point Site No. 7

LAB NO.	DEPTH (~~Cm.~~ M)	PROFILE DESCRIPTION
12,303 T-1143	0-.3	A_p 0-.15 meters, dark grayish brown (10YR 4/2) heavy loam, very dark grayish brown (10YR 3/2) moist; moderate, medium, blocky structure; slightly hard, friable moist, slightly sticky, slightly plastic wet; plentiful, fine roots; abrupt boundary.
		B_{2t} .15-.25 meters, brown (10YR 5/3) clay loam, dark grayish brown (10YR 3/2) moist; moderate, medium, prismatic structure breaks to moderate, medium, blocky structure; hard dry, friable moist, sticky, plastic wet; common, thin clay skins on ped face; plentiful, fine roots; noncalcareous; abrupt boundary.
		B_{3ca} .25-.30 meters, brown (10YR 5/3) clay loam, dark brown (10YR 3/3) moist; moderate, coarse, prismatic structure breaks to moderate, medium, blocky structure; hard dry, friable moist, sticky, plastic wet; plentiful, fine roots; strongly calcareous; gradual boundary.
12,304 T-1144	.3-.76	C_{ca} .30-.76 meters, grayish brown (2.5y 5/2) clay loam, very dark grayish brown (2.5y 3/2) moist; weak, coarse blocky structure, breaks to moderate, medium, blocky structure; hard dry, friable moist, sticky, plastic wet; few, fine roots; strong violently calcareous; gradual boundary.
12,305 T-1145	.76-1.2	C_{2ca} .76-1.2 meters, pale brown (10YR 6/3) heavy clay loam, grayish brown (10YR 5/2) moist; weak, coarse, blocky structure breaks to moderate, medium, blocky structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; gradual boundary.
12,306 T-1146	1.2-1.8	C_{31} 1.2-1.8 meters, light brownish gray (10YR 6/2) clay loam, grayish brown (10YR 5/2) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous; diffuse boundary.
12,307 T-1147	1.8-2.7	C_{32} 1.8-2.4 meters, light brownish gray (10YR 6/2) weathered shale heavy clay loam, very dark grayish brown (10YR 4/2) moist; massive structure; very hard dry, firm moist, sticky, plastic wet; strongly calcareous; diffuse boundary.
		IIC_4 2.4-2.7 meters, heavy clay loam sandy shale colors vary from grayish brown (10YR 5/2) to brownish yellow (10YR 6/6) dry, to a dark gray (10YR 4/1) and yellowish brown (10YR 5/6) moist; massive structure; very hard dry, firm moist, sticky, plastic wet; strongly calcareous.

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		12,303	12,304	12,305	12,306	12,307
DEPTH	(m)	0-.3	.3-.76	.76-1.2	1.2-1.8	1.8-2.7
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0mm)					
Coarse Sand	(1.0-0.5mm)					
Medium Sand	(0.5-0.25mm)					
Fine Sand	(0.25-0.10mm)					
Very Fine Sand	(0.10-0.05mm)					
Total Sand	(2.0-0.05mm)	48.1	19.9	27.0	24.5	22.9
Silt	(0.05-0.002mm)	31.5	40.9	52.8	62.8	64.5
Clay	(<0.002mm)	20.4	39.2	20.2	13.5	12.6
TEXTURAL CLASS (LAB)		L	SiCL	SiL	SiL	SiL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(cm/hr)					
6th hr		0.93	0.25	0.31	0.12	0.39
24th hr		0.19	0.33	0.31	0.15	0.39
SETTLING VOLUME	(ml)	21	24	22	21	20
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		9.7	16.1	8.7	6.8	5.9
SOIL REACTION-pH						
Paste						
1:5 H_2O		7.4	8.2	8.7	9.2	8.9
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	+0.6	-13.	-12.	-0.9	-3.4
SATURATION EXTRACT						
Saturation Percentage		32.8	53.4	46.9	43.9	41.4
EC_e @ 25°C	(mmhos/cm)	0.4	9.8	11.9	7.7	8.3
Ca^{++}	(me/l)	1.13	24.04	22.33	5.94	21.29
Mg^{++}	(me/l)	0.91	83.59	101.50	35.82	45.77
Na^{+}	(me/l)	2.09	55.24	75.76	57.87	51.56
K^{+}	(me/l)	0.43	0.15	0.13	0.08	0.09
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	2.35	4.25	2.32	2.25	1.59
Cl^{-}	(me/l)	0.20	2.40	3.08	2.29	1.17
SO_4^{-}	(me/l)	1.49	145.83	171.88	96.79	122.04
NO_3^{-}	(me/l)	0.01	0.02	0.15	0.14	0.10
SAR	(me/l)	2.1	7.5	9.6	13.	8.9
Na	(me/100g)	0.07	2.95	3.55	2.54	2.13
Ca+Mg	(me/100g)	0.07	5.74	5.81	1.83	2.77
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	3.45	2.75	1.01	1.26	0.12
Ca+Mg	(me/l)	0.36	46.90	27.00	2.88	8.42
EXCHANGEABLE SODIUM	(percent)	2.1	5.1	5.4	12.	7.8
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	13.3	20.9	11.5	9.1	8.3
NaOAc@pH 8.2						
BORON	(mg/l)					

Remarks: This pedon has higher EC than is typical for series
Borders Belfield series Clay % in .76 to 1.8 meters questionable

Table 22

GPO 833-276

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Rattlesnake Butte
Location. Sec. 22 Twp. 140 N. Range 98 W.
1100'E., 500'N. of S¼ corner
Climate: Semi-Arid
Land Use: Cultivated

Relief: Simple, nearly level
Elevation: 2540
Slope: Aspect: North
Vegetation: Small Grain
Erosion: Slight

Stoniness: None
Drainage: Moderately Well Drained
Ground Water: None
Land Form: Residual

Parent Material: Soft shale
Soil Series: Moreau
Soil Classification: Typic Haploborolls
fine, montmorillonitic
Profile Description By: T. Fiechtl Date: 8/78
Correlated By: G. Muckel 5/79

Point Site No. 7

LAB NO.	DEPTH (M) (~~Cm.~~)	PROFILE DESCRIPTION
12,282 T-1119	0-.45	A_p 0-.15 meters, brown (10YR 5/3) silty clay loam, very dark brown (10YR 3/2) moist; moderate, medium, coarse blocky structure; very hard dry, friable moist, sticky, plastic wet; plentiful, fine roots; noncalcarcous; abrupt boundary.
		B_{2t} .15-.30 meters, grayish brown (10YR 5/2) silty clay loam, very dark brown (10YR 3/2) moist; weak, medium, coarse prismatic structure, breaks to moderate, medium, blocky structure; hard dry, friable moist, sticky, plastic wet; thin continuous clay skins on ped face; plentiful, fine roots; noncalcareous; abrupt boundary.
		B_{3ca} .30-.45 meters, light brownish gray (10YR 6/2) heavy silty clay loam, grayish brown (10YR 5/2) moist; weak coause, prismatic structure, breaks to moderate, medium, blocky structure; few fine roots; strongly calcareous; abrupt boundary.
12,283 T-1120	.45-.76	C_{ca} .45-.76 meters, brown (10YR 5/3) silty clay, dark grayish brown (10YR 4/2) moist; weak, coarse, blocky structure; hard dry, friable moist, sticky, plastic wet; few fine roots; strongly calcareous; abrupt boundary.
12,284 T-1121	.76-1.3	C_2 .76-1.3 meters, brown (10YR 5/3) weathered shale, dark brown (10YR 3/3) moist; massive structure; very hard dry, firm moist, sticky, plastic wet; strongly calcareous; gradual boundary.
12,285 T-1122	1.3-1.9	C_{31} 1.3-1.9 meters, sandy shale material varies from a grayish brown (10YR 5/2) light clay, light gray (10YR 7/2) moist; a brown (10YR 5/3) to a brownish yellow (10YR 6/6) moist; dark brown (7.5YR 3/2) to a brown (7.5YR 5/3) moist, color variations due to numerous stratifications of materials influenced by sedimentary variations, degree of oxidation, carbonaceous influence; massive structure; very hard dry, firm moist, sticky, plastic wet; noncalcareous; gradual boundary.
12,286 T-1123	1.9-2.5	C_{32} 1.9-2.5 meters, sandy shale material varies from a grayish brown (10YR 5/2) light clay, light gray (10YR 7/2) moist; a brown (10YR 5/3) to a brownish yellow (10YR 6/6) moist; dark brown (7.5YR 3/2) to a brown (7.5YR 5/3) moist, color variations due to numerous stratifications of materials influenced by sedimentary variations, degree of oxidation, carbonaceous influence; massive structure; very hard dry, firm moist, sticky, plastic wet; noncalcareous; gradual boundary.
12,287 T-1124	2.5-3.0	C_{33} 2.5-3.0 meters, sandy shale material varies from a grayish brown (10YR 5/2) light clay, light gray (10YR 7/2) moist; a brown (10YR 5/3) to a brownish yellow (10YR 6/6) moist; dark brown (7.5YR 3/2) to a brown (7.5YR 5/3) moist, color variations due to numerous stratifications of materials influenced by sedimentary variations, degree of oxidation, carbonaceous influence; massive-structure; very hard dry, firm moist, sticky, plastic wet; noncalcareous; gradual boundary.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		12,282	12,283	12,284	12,285	12,286	12,287
DEPTH	(m)	0-.45	.45-.76	.76-1.3	1.3-1.9	1.9-2.5	2.5-3.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0mm)						
Coarse Sand	(1.0-0.5mm)						
Medium Sand	(0.5-0.25mm)						
Fine Sand	(0.25-0.10mm)						
Very Fine Sand	(0.10-0.05mm)						
Total Sand	(2.0-0.05mm)	18.3	5.9	1.6	1.6	2.5	2.5
Silt	(0.05-0.002mm)	43.6	46.5	52.6	31.7	30.0	33.4
Clay	(<0.002mm)	38.1	47.6	45.8	66.7	67.5	64.1
TEXTURAL CLASS (LAB)		SiCL	SiC	SiC	C	C	C
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(cm/hr)						
6th hr		0.08	*2/3	*2/3	*2/3	*1/2	*1/2
24th hr		0.06	*3/4	**3/4	*0.01	*2/3	*3/4
SETTLING VOLUME	(ml)	19	70	98	152	82	102
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		10.9	15.1	7.0	11.0	10.3	10.0
SOIL REACTION-pH		9.0	9.1	8.8	8.7	8.4	8.4
Paste							
1:5 H_2O							
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+0.4	+2.8	+1.2	-3.0	-2.4	-2.8
SATURATION EXTRACT		31.5	42.5	102.9	143.4	111.4	111.6
Saturation Percentage		0.6	1.1	8.7	10.2	15.1	13.4
EC_e @ 25°C	(mmhos/cm)	0.80	0.55	20.96	19.53	20.41	20.74
Ca^{++}	(me/l)	0.79	0.36	22.89	23.88	42.79	31.84
Mg^{++}	(me/l)	4.40	10.19	73.13	94.17	157.83	140.47
Na^{+}	(me/l)	0.06	0.04	0.15	0.12	0.18	0.20
K^{+}	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
CO_3^{-}	(me/l)	4.82	4.21	1.57	1.41	1.36	2.81
HCO_3^{-}	(me/l)	0.11	0.11	0.16	0.20	0.06	0.08
Cl^{-}	(me/l)	1.27	6.67	119.10	122.92	219.79	181.25
SO_4^{-}	(me/l)	0.09	0.02	0.10	0.24	1.67	1.05
NO_3^{-}	(me/l)	4.9	15.	16.	20.	28.	27.
SAR		0.14	0.43	7.53	13.50	17.58	16.52
Na	(me/100g)	0.05	0.04	4.52	6.22	7.01	6.18
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.21	0.42	2.9	3.95	5.10	5.40
Ca+Mg	(me/l)	0.71	0.55	5.44	15.60	23.00	33.70
EXCHANGEABLE SODIUM	(percent)	5.6	21.	8.9	14.	19.	18.
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	14.6	16.1	16.0	20.9	24.3	26.1
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 23

Remarks: This pedon has high SAR.

*Denotes that no water was transmitted through soil column prior to and during specified period

GPO 833-796

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Rattlesnake Butte
Locotion. Sec. 10 Twp. 140 N. Ronge 98 W.
200'E., 100'S., of N¼ corner
Climote: Semi-Arid
Lond Use: Cultivated

Relief: Complex, undulating
Elevotion: 2640
Slope: Aspect: North
Vegetation: Small Grain
Erosion: Slight

Stoniness: None
Drainoge: Well Drained
Ground Water: None
Lond Form: Bench Remnant

Porent Materiol: Colluvial over soft shale
Soil Series: Farland
Soil Classificotion: Typic Argiborolls fine-silty, mixed
Profile Description By: T. Fiechtl Dote: 8/78
Correlated By: C. Muckel 5/79

Point Site No. 8

LAB NO.	DEPTH (~~Cm.~~ M)	PROFILE DESCRIPTION
12,308 T-1150	0-.3	A_p 0-.15 meters, grayish brown (10YR 5/2) light clay loam, very dark grayish brown (10YR 3/2) moist; weak, medium, blocky structure separates to weak, coarse, crumb structure; slightly hard dry, friable moist, slightly sticky, slightly plastic wet; plentiful, fine roots; noncalcareous; abrupt boundary.
		B_{2t} .15-.30 meters, grayish brown (10YR 5/2) clay loam, dark brown (10YR 3/2) moist; moderate, medium, prismatic structure breaks to moderate, medium, blocky structure; slightly hard dry, friable moist, sticky, plastic wet; many, thin clay films on ped faces; plentiful, fine roots; noncalcareous; gradual boundary.
12,309 T-1151	.3-.76	B_3 .30-.76 meters, grayish brown (10YR 5/2) heavy clay loam, dark brown (10YR 3/3) moist; moderate, medium, prismatic structure breaks to moderate, medium, blocky structure; hard dry, friable moist, sticky, plastic wet; plentiful, fine roots; noncalcareous; gradual boundary.
12,310 T-1153	.76-1.2	C_1 .76-1.2 meters, light brownish gray (10YR 6/2) heavy clay loam, dark grayish brown (10YR 4/2) moist; weak, very coarse, blocky structure; very hard dry, firm moist, sticky, plastic wet; few, fine roots; slightly calcareous, gradual boundary.
12,311 T-1154	1.2-1.6	C_2 1.2-1.6 meters, pale brown (10YR 6/3) silty clay, dark grayish brown (10YR 4/2) moist; massive structure; very hard dry, firm moist, sticky, plastic wet; strongly calcareous; gradual boundary.
12,312 T-1155	1.6-2.1	IIC_3 1.6-2.1 meters, grayish brown (10YR 6/2) light clay; light brownish gray (10YR 5/2) moist, mottling influence from a brownish yellow (10YR 6/6) dry, yellowish brown (10YR 5/6) moist; massive structure; hard dry, firm moist, sticky, plastic wet; slightly calcareous; abrupt boundary.
12,313 T-1156	2.1-3.0	C_4 2.1-2.5 meters, gray (10YR 6/1) light clay, dark gray (10YR 4/1) moist; massive structure; hard dry, firm moist, sticky, plastic wet; noncalcareous; abrupt boundary; organic carbon influenced horizon.
		C_5 2.5-3.0 meters, light gray (10YR 7/2) light clay, light brownish gray (10YR 6/2) moist, with strong brown mottling (7.5YR 5/6) dry, dark brown (7.5YR 4/3) moist; massive structure; extremely hard dry, very firm moist, sticky, plastic wet; noncalcareous semiconsolidated sandy shale.

LABORATORY DESCRIPTION

DETERMINATION		12,308	12,309	12,310	12,311	12,312	12,313
LABORATORY NUMBER							
DEPTH	(m)	0-.3	.3-.76	.76-1.2	1.2-1.6	1.6-2.1	2.1-3.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0mm)						
Coarse Sand	(1.0-0.5mm)						
Medium Sand	(0.5-0.25mm)						
Fine Sand	(0.25-0.10mm)						
Very Fine Sand	(0.10-0.05mm)						
Total Sand	(2.0-0.05mm)	37.5	26.7	19.2	11.3	13.2	12.6
Silt	(0.05-0.002mm)	39.7	47.7	41.6	39.5	23.3	34.9
Clay	(<0.002mm)	22.8	25.6	39.2	49.2	63.5	52.5
TEXTURAL CLASS (LAB.)		L	L	SiCL	C	C	C
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(cm/hr)						
6th hr		0.16	0.04	*	0.02	0.04	*2/3
24th hr		0.12	0.04	*	0.02	0.04	*9/10
SETTLING VOLUME	(ml)	22	23	27	31	44	48
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		11.8	12.1	15.7	19.1	27.0	26.8
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.0	6.2	6.9	8.1	8.5	8.3
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+0.2	-0.2	+0.2	-1.8	-1.8	+1.9
SATURATION EXTRACT							
Saturotian Percentage		42.6	47.0	55.0	66.1	91.0	97.0
EC_e @ 25°C	(mmhos/cm)	1.0	0.7	0.6	4.3	4.4	3.7
Ca^{++}	(me/l)	3.52	2.04	1.40	26.13	14.52	4.24
Mg^{++}	(me/l)	3.35	2.17	2.60	22.34	21.08	11.13
Na^{+}	(me/l)	1.29	1.44	2.57	11.05	19.37	24.87
K^{+}	(me/l)	0.59	0.22	0.11	0.21	0.23	0.38
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	0.74	0.42	4.25	1.83	1.53	4.15
Cl^{-}	(me/l)	0.10	0.08	0.07	0.14	0.12	0.13
SO_4^{-}	(me/l)	1.53	2.08	2.33	52.60	54.83	32.73
NO_3^{-}	(me/l)	6.67	3.83	0.13	4.42	5.58	3.83
SAR	(me/l)	0.7	1.0	1.8	2.2	4.6	9.0
Na	(me/100g)	0.05	0.07	0.14	0.73	1.76	2.41
Ca+Mg	(me/100g)	0.29	0.20	0.22	3.21	3.24	1.49
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.09	0.17	0.95	1.13	0.88	1.40
Ca+Mg	(me/l)	0.75	0.59	1.07	8.60	7.10	1.62
EXCHANGEABLE SODIUM	(percent)	0.8	1.1	2.3	3.1	5.9	10.
ACIDITY							
1N KCl exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	16.9	19.7	23.5	20.7	20.9	23.5
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 24

Remarks: The agrillic is in question; the lab data sampling was not done on .15 to .30 meters. It was assumed to be less than 15% fs and coarser
Sample Number T-1152 omitted

*Denotes that no water was transmitted through Soil Column to and during specified testing period

GPO 833-796

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: Rattlesnake Butte
Lacation. Sec. 26 Twp. 140W Range 99W
400'E., 150'S., W¼ corner
Climate: Semi-Arid
Land Use: Cultivated

Relief: Complex, Undulating
Elevatian: 2600
Slape: Aspect: East
Vegetatian: Small Crain
Erasian: Slight

Staniness: None
Drainage: Somewhat Excessively Drained
Graund Water: None
Land Farm: High Stream Terrace

Parent Material: Sandy Alluvium
Sail Series: Parshall
Sail Classificatian: Pachic Haploborolls coarse loamy, mixed.
Prafile Descriptian By: T. Piechtl Date: 8/78
Correlated By: C. Muckel 5/79

Point Site No. 7

LAB NO.	DEPTH (M ~~Cm.~~)	PROFILE DESCRIPTION
12,276 T-1113	0-.3	A_p 0-.15 meters, dark grayish brown (10YR 4/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist, weak medium, blocky structure, breaks to moderate medium, blocky structure: slightly hard dry, friable moist, nonsticky, nonplastic wet: plentiful, fine roots: noncalcareous; abrupt boundary.
		B_{21} .15-.30 meters, brown (10YR 4/3) fine sandy loam, dark grayish brown (10YR 4/2) moist: weak, medium, prismatic structure breaks to moderate, medium, blocky structure; slightly hard dry, friable moist, nonsticky, nonplastic wet; plentiful, fine roots; noncalcareous; gradual boundary.
12,277 T-1114	.3-.76	B_{22} .30-.76 meters, brown (10YR 5/3) fine sandy loam, dark brown (10YR 3/3) moist; weak, medium, prismatic structure, breaks to moderate, medium, blocky sturcture; slightly hard dry, friable moist, nonsticky, nonplastic wet; few fine roots; noncalcareous; gradual boundary.
12,278 T-1115	.76-1.3	B_3 .76-1.3 meters, brown (10YR 5/3) light fine sandy loam, dark grayish brown (10YR 4/2) moist; weak, moderate, prismatic structure, breaks to moderate, medium, blocky structure; slightly hard dry, friable moist, nonsticky, nonplastic wet; (slightly $CaCo_3$ below 35"): gradual boundary.
12,279 T-1116	1.3-1.9	C_{r1} 1.3-1.6 meters, brown (10YR 5/3) fine sandy loam, dark brown (10YR 4/3) moist; massive structure; slightly hard dry, very friable moist, nonsticky, nonplastic wet; strongly calcareous; abrupt boundary.
		C_{r2} 1.6-1.9 meters, grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; massive structure; slightly hard dry, friable moist, nonsticky, nonplastic wet; strongly calcareous; abrupt boundary.
12,280 T-1117	1.9-2.5	C_{r3} 1.9-2.5 meters, pale brown (10YR 6/3) loamy fine sand, brown (10YR 5/3) moist; massive structure; soft dry, loose moist, nonsticky, nonplastic wet; strongly calcareous; abrupt boundary.
12,281 T-1118	2.5-3.0	C_{r4} 2.5-3.0 meters, pale brown (10YR 4/3) sandy shale, light fine sandy loam, grayish brown (10YR 5/2) moist; mottling varies from yellowish brown (10YR 5/6) dry, dark yellowish brown (10YR 4/4) moist; massive structure; slightly hard dry, very friable moist, nonsticky, nonplastic wet; strongly calcareous.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		12,276	12,277	12,278	12,279	12,280	12,281
DEPTH	(m)	0-.3	.3-.76	.76-1.3	1.3-1.9	1.9-2.5	2.5-3.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0mm)	0.5	0.2	9.2	0.9	0.8	0.6
Coarse Sand	(1.0-0.5mm)	6.4	5.0	5.3	4.3	6.5	10.8
Medium Sand	(0.5-0.25mm)	28.2	24.1	23.3	14.9	23.5	34.6
Fine Sand	(0.25-0.10mm)	34.2	38.9	40.0	38.4	39.2	29.4
Very Fine Sand	(0.10-0.05mm)	6.4	7.3	7.6	7.2	6.4	5.5
Total Sand	(2.0-0.05mm)	75.7	75.5	75.4	65.7	76.4	80.9
Silt	(0.05-0.002mm)	14.3	13.9	14.1	22.9	15.9	11.7
Clay	(<0.002mm)	10.0	10.6	10.5	11.4	7.7	7.4
TEXTURAL CLASS (LAB)		SL	FSL	FSL	FSL	SL	LS
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(cm/hr)						
6th hr		3.15	3.15	3.35	2.36	4.99	5.34
24th hr		3.54	3.70	3.72	2.68	4.16	5.58
SETTLING VOLUME	(ml)	18	17	18	19	18	17
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		6.5	6.2	6.3	7.4	5.7	5.6
SOIL REACTION-pH							
Paste							
1:5 H_2O		6.4	6.7	7.4	8.2	8.6	8.7
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	0.0	0.0	0.0	0.0	-0.4	0.0
SATURATION EXTRACT							
Saturation Percentage		29.1	28.7	31.5	34.1	34.5	31.5
EC_e @ 25°C	(mmhos/cm)	0.3	0.2	0.4	0.4	0.4	0.4
Ca^{++}	(me/l)	2.42	1.57	3.30	2.85	2.24	2.01
Mg^{++}	(me/l)	0.69	0.53	0.81	0.53	0.76	0.71
Na^{+}	(me/l)	0.19	0.33	0.37	0.48	0.73	1.29
K^{+}	(me/l)	0.20	0.05	0.05	0.05	0.05	0.06
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	2.18	1.68	3.65	2.71	2.61	2.99
Cl^{-}	(me/l)	0.14	0.10	0.11	0.11	0.11	0.09
SO_4^{-}	(me/l)	0.26	0.37	0.42	0.49	0.70	0.49
NO_3^{-}	(me/l)	0.25	0.09	0.18	0.30	0.20	0.33
SAR	(me/l)	0.2	0.3	0.3	0.4	0.6	1.1
Na	(me/100g)	0.01	0.01	0.01	0.02	0.03	0.04
Ca+Mg	(me/100g)	0.09	0.07	0.13	0.12	0.11	0.08
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.06	0.04	0.13	0.15	0.12	0.12
Ca+Mg	(me/l)	0.55	0.52	1.26	1.34	1.05	0.88
EXCHANGEABLE SODIUM	(percent)	1.5	2.1	1.1	1.1	2.1	3.8
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	7.1	6.8	7.0	8.3	6.1	5.8
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 25

GPO 833-796

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Rattlesnake Butte | Relief: Complex, Undulating | Stoniness: None | Porent Moteriol: Soft shale, sandstone

Locotion. Sec. 20 Twp. 140 N Ronge 98 W | Elevotion: 2620 | | Soil Series: Daglum like

1300'N., 100'E., of W¼ corner | Slope: Aspect: South East | Drainoge: Well Drained | Soil Classificotion: Typic Natriborolls

Climate: Semi-Arid | Vegetation: Small Grain | Ground Woter: None | fine, montmorillonitic

Lond Use: Cultivated | Erosion: Slight | Lond Form: Colluvial, deep | Profile Description By: T. Fiechtl Dote: 8/78

Correlated By: C. Muckel 5/79

Point Site No. 5

LAB NO.	DEPTH (M) (Cm.)	PROFILE DESCRIPTION
12,292 T-1131	0-.30	A_1 0-.05 meters, dark grayish brown (10YR 4/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; moderate, medium, granular structure; soft dry, very friable moist, nonsticky, nonplastic wet; plentiful, fine roots; noncalcareous; abrupt boundary.
		B_{12} .05-.25 meters, dark grayish brown to brown (10YR 4/2) light clay loam, very dark grayish brown (10YR 3/2) moist; moderate, medium, prismatic structure breaks to moderate, medium blocky structure; very hard dry, friable moist, sticky, slightly plastic wet: plentiful, fine roots; noncalcareous; abrupt boundary.
		B_{22t} .25-.30 meters, grayish brown (10YR 5/2) heavy clay loam, dark grayish brown (10YR 4/2) moist; moderate, medium, prismatic structure breaks to moderate, medium blocks, very hard dry, friable moist, sticky and plastic wet; many thin clay films on ped faces; noncalcareous; gradual boundary.
12,293 T-1132	.30-.61	B_{3ca} .30-.61 meters, grayish brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) moist; moderate, medium, prismatic structure breaks to moderate, medium blocks; very hard dry, friable moist, sticky, plastic wet; strongly calcareous; gradual boundary.
12,294 T-1133	.61-1.2	C_{cs} .61-.76 meters, brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist: weak, coarse, prismatic structure breaks to moderate, coarse, blocky structure; very hard dry, friable moist, sticky, plastic wet; few, fine roots; common fine masses of precipitated salts strongly calcareous; gradual boundary.
		C_2 .76-1.2 meters, pale brown (10YR 6/3) clay loam, grayish brown (10YR 5/2) moist; weak, coarse, blocky structure; very hard dry, friable moist, sticky, plastic wet; strongly calcareous.
12,295 T-1134	1.2-1.8	IIC_3 1.2-1.8 meters, pale brown (10YR 6/3) very fine sandy loam, grayish brown (10YR 6/2) moist; massive structure; slightly hard dry, loose moist, slightly sticky, nonplastic wet; slightly calcareous; diffuse boundary.
12,296 T-1135	1.8-2.4	C_4 1.8-2.4 meters, light gray (10YR 7/2) very fine sandy loam, light brownish gray (10YR 6/2) moist; massive structure; slightly hard dry, loose moist, slightly sticky, nonplastic wet; slightly calcareous; diffuse boundary.
12,297 T-1136	2.4-3.0	C_5 2.4-2.7 meters, light gray (10YR 7/2) fine sandy loam, light brownish gray (10YR 6/2) moist; massive structure; slightly hard dry, soft moist, nonsticky, nonplastic wet; slightly calcareous; diffuse boundary.
		$IIIC_6$ 2.7-3.0 meters, very pale brown (10YR 7/3) light sand clay loam, brown (10YR5/3) moist; mottling influenced; pale brown (10YR 6/3) to brown (10YR 5/3) moist; massive structure; hard dry, friable moist, slightly sticky, slightly plastic wet; noncalcareous.

Remarks: clay content bordering fine-silty family.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		12,292	12,293	12,294	12,295	12,296	12,297
DEPTH	(m)	0-.3	.3-.61	.61-1.2	1.2-1.8	1.8-2.4	2.4-3.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5mm)						
Medium Sand	(0.5-0.25mm)						
Fine Sand	(0.25-0.10mm)						
Very Fine Sand	(0.10-0.05mm)						
Total Sand	(2.0-0.05mm)	26.3	26.2	14.6	7.3	8.4	2.2
Silt	(0.05-0.002mm)	44.2	40.4	49.4	58.1	46.2	48.4
Clay	(<0.002 mm)	29.5	33.4	36.0	34.6	45.4	49.4
TEXTURAL CLASS (LAB)		CL	CL	SiCL	SiCL	SiC	SiC
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(cm/hr)						
6th hr		0.06	0.04	*2/4	*2/3	*1/3	*1/3
24th hr		0.08	0.06	*3/4	*3/4	*1/2	*1/2
SETTLING VOLUME	(ml)	.45	.31	45	45	44	52
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		12.8	20.3	12.3	15.9	17.3	19.1
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.5	8.6	9.1	9.0	9.1	9.1
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+0.5	-13.	-6.0	-5.2	-2.4	-2.8
SATURATION EXTRACT							
Saturation Percentage		49.0	59.3	71.8	72.1	81.7	87.4
EC_e @ 25°C	(mmhos/cm)	1.7	9.5	15.2	17.5	19.2	21.9
Ca^{++}	(me/l)	3.14	21.78	21.18	20.63	20.13	20.08
Mg^{++}	(me/l)	2.89	32.84	55.72	60.70	69.65	72.64
Na^{+}	(me/l)	12.91	80.49	148.88	185.18	209.38	232.00
K^{+}	(me/l)	0.14	0.08	0.12	0.13	0.12	0.11
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	4.94	1.94	1.61	1.85	1.49	1.57
Cl^{-}	(me/l)	0.12	0.21	0.12	0.11	0.08	0.08
SO_4^{-}	(me/l)	15.60	118.75	216.67	260.42	294.79	302.08
NO_3^{-}	(me/l)	0.01	0.24	1.40	2.67	4.17	7.67
SAR	(me/l)	7.4	15.	24.	29.	31.	34.
Na	(me/100g)	0.63	4.77	10.69	13.55	17.11	20.28
Ca+Mg	(me/100g)	0.29	3.15	5.52	5.87	7.33	8.60
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.37	3.40	3.50	5.10	5.50	6.30
Ca+Mg	(me/l)	1.18	35.40	19.50	32.90	19.30	38.00
EXCHANGEABLE SODIUM	(percent)	9.1	13.	16.	22.	13.	12.
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	13.9	12.4	15.0	14.3	22.0	17.2
NaOAc@pH 8.2							
BORON	(mg/l)						

*Denotes that no water was transmitted through soil column prior to and during specified testing period

Table 26

GPO 833-796

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: Rattlesnake Butte
Relief: Simple, nearly level
Stoniness: None
Parent Material: Soft Shale
Location. Sec. 14 Twp. 140N Range 99W
Elevation: 2575
Soil Series: Rhoades
1000'E. of SW. corner
Slope: Aspect: North
Drainage: Moderately well to imperfectly drained
Soil Classification: fine, montmorillonitic Leptic Natriborolls
Climate: Semi-Arid
Vegetation: Gramma
Ground Water: 2.4 meters
Land Use: Pasture
Erosion: Slight
Land Form: Colluvial bottom
Profile Description By: T. Piechtl Date: 8/78
Correlated By: G. Muckel 5/79

Point Site No. 9

LAB NO.	DEPTH (M) (Cm.)	PROFILE DESCRIPTION
12,288 T-1125	0-.45	A_{12} 0-.05 meters, light brownish gray (10YR 6/2) silt loam, dark grayish brown (10YR 4/2) moist; moderate, medium platy structure breaks to moderate, medium, crumb structure; slightly hard dry, very friable moist, sticky, slightly plastic wet; plentiful, fine roots; noncalcareous; abrupt boundary.
		AB .05-.10 meters, light brownish gray (10YR 6/2) heavy clay loam, dark grayish brown (10YR 4/2) moist; weak, medium, prismatic structure, breaks to moderate, medium, blocky structure; slightly hard dry, friable moist, sticky, plastic wet; plentiful, fine roots; noncalcareous; gradual boundary.
		B_{2t} .10-.22 meters, grayish brown (10YR 5/2) heavy clay loam, very dark grayish brown (10YR 3/2) moist; moderate, medium, columnar prismatic structure, breaks to moderate, medium, blocky structure; very hard dry, firm moist, sticky, plastic wet; thin, continuous clay skins on ped face; plentiful, fine roots, noncalcareous; gradual boundary.
		B_{3ca} .22-.45 meters, light grayish brown (10YR 6/2) heavy clay loam, dark grayish brown (10YR 4/2) moist; weak, coarse, prismatic structure breaks to moderate, medium blocky structure; slightly hard dry, friable moist, sticky, plastic wet; plentiful, fine roots; many fine masses of precipitated salts strongly calcareous; gradual boundary.
12,289 T-1126	.45-1.1	C_{ca} .45-1.1 meters, pale brown (10YR 6/3) clay loam, brown (10YR 4/3) moist; mottles in lower parts weak, coarse blocky structure breaks to moderate, medium, blocky structure; very hard dry, firm moist, sticky, plastic wet; few, fine roots; many fine masses of precipitated salts strongly calcareous; gradual boundary.
12,290 T-1127	1.1-1.6	C_2 1.1-1.6 meters, pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; massive structure; very hard dry, firm moist, sticky, plastic wet; strongly calcareous; gradual boundary.
12,291 T-1128	1.6-2.4	C_3 1.6-2.4 meters, light brownish gray (10YR 6/2) clay loam, grayish brown (10YR 5/2) moist; massive structure; very hard dry, firm moist, sticky, plastic wet; strongly calcareous.

LABORATORY DESCRIPTION

DETERMINATION		DATA			
LABORATORY NUMBER		12,288	12,289	12,290	12,291
DEPTH	(m)	0-.45	.45-1.1	1.1-1.6	1.6-2.4
PARTICLE SIZE ANALYSIS	(percent)				
Very Coarse Sand	(2.0-1.0 mm)				
Coarse Sand	(1.0-0.5 mm)				
Medium Sand	(0.5-0.25 mm)				
Fine Sand	(0.25-0.10 mm)				
Very Fine Sand	(0.10-0.05 mm)				
Total Sand	(2.0-0.05 mm)	7.3	8.4	15.6	15.6
Silt	(0.05-0.002 mm)	47.7	55.6	54.4	49.4
Clay	(<0.002 mm)	45.0	36.0	30.0	35.0
TEXTURAL CLASS (LAB)		Sic	Sicl	Sicl	Sicl
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(cm/hr)				
6th hr		*3/4	*3/4	*1/2	*3/4
24th hr		0.01	*	*2/3	*
SETTLING VOLUME	(ml)	29	34	62	51
MOISTURE RETENTION	(percent)				
1/10 bar					
1/3 bar					
15 bar		4.5	7.6	12.9	15.5
SOIL REACTION-pH					
Paste					
1:5 H_2O		8.2	9.0	9.5	9.1
1:2 0.01 M $CaCl_2$					
ORGANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
$CaCO_3$ EQUIVALENT	(percent)				
GYPSUM REQUIREMENT	(me/100g)	-1.0	-2.0	+3.6	+1.5
SATURATION EXTRACT					
Saturation Percentage		65.0	64.2	80.0	73.9
EC_e @ 25°C	(mmhos/cm)	7.7	12.9	3.6	2.1
Ca^{++}	(me/l)	21.29	19.80	1.32	1.60
Mg^{++}	(me/l)	33.83	65.67	4.16	2.35
Na^{+}	(me/l)	54.71	112.06	32.67	18.03
K^{+}	(me/l)	0.42	0.21	0.07	0.09
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	5.50	1.96	3.99	3.55
Cl^{-}	(me/l)	0.20	0.14	0.10	0.12
SO_4^{-}	(me/l)	105.21	186.46	32.73	18.42
NO_3^{-}	(me/l)	0.02	0.02	0.22	0.35
SAR	(me/l)	10.	17.	20.	13.
Na	(me/100g)	3.56	7.19	2.61	1.33
Ca+Mg	(me/100g)	3.58	5.49	0.44	0.29
1:5 EXTRACT					
EC_5 @ 25°C	(mmhos/cm)	1.75	2.50	0.80	0.48
Ca+Mg	(me/l)	1.10	9.00	0.55	0.71
EXCHANGEABLE SODIUM	(percent)	12.	14.	24.	12.
ACIDITY					
1N KCl exchange acidity					
Total	(me/100g)				
Al^{+++}	(me/100g)				
CATION EXCHANGE CAPACITY	(me/100g)	18.0	14.2	13.9	18.4
NaOAc@pH 8.2					
BORON	(mg/l)				

*Denotes that no water was transmitted through soil column prior to and during apecified testing period

Table 27

GPO 833-796

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
WATER AND POWER RESOURCES SERVICE
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOCIC CORE ANALYSIS
DH-78-101

Study Area: Rattlesnake Butte, North Dakota Relief: Stoniness: Parent Material:

Location. Sec. ____ Twp. ____ Range ____ Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Ground Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (ppm)					
Laboratory Number		11,701	11,702	11,703	11,704	11,705	11,706
Sack Number		101-1	101-2	101-3	101-4	101-5	101-6
Depth (Ft)		0-20.0	20.0-40.0	40.0-67.0	67.0-80.0	80.0-103.4	103.4-122.9
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.1	0.9	0.3	0.0	2.1	0.0
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	1.12	0.22	0.50	0.12	0.16	0.04
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	8.6	9.6	11.6	5.0	8.0	1.0
IRON	Fe	308.0	74.0	64.0	98.0	76.0	28.8
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	7.8	17.6	19.6	15.2	17.2	3.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	2.2	4.4	5.0	1.8	4.0	2.0
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	3.4	4.7	11.4	6.6	9.4	7.2

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		11,701	11,702	11,703	11,704	11,705	11,706
Sack Number		101-1	101-2	101-3	101-4	101-5	101-6
DEPTH	(Ft)	0-20.0	20.0-40.0	40.0-67.0	67.0-80.0	80.0-103.4	103.4-122.9
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						0.1
Coarse Sand	(1.0-0.5 mm)						0.1
Medium Sand	(0.5-0.25 mm)						0.3
Fine Sand	(0.25-0.10 mm)						28.5
Very Fine Sand	(0.10-0.05 mm)						36.0
TOTAL SAND	(2.0-0.05 mm)	11.4	11.4	26.8	22.8	8.3	65.0
SILT	(0.05-0.002 mm)	48.4	35.0	38.8	57.0	87.3	16.0
CLAY	(0.002 mm)	40.2	53.6	34.4	20.2	4.4	19.0
TEXTURAL CLASS (LAB)		SIC	C	CL	SiL	Si	VFSL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.		0.01	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	43	122	100	77	95	95
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		18.9	28.1	35.5	32.7	33.4	39.2
SOIL REACTION-pH							
Paste							
1:5 H_2O							
1:2 0.01 M $CaCl_2$		7.6	8.8	9.6	10.0	9.9	10.2
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)						
SATURATION EXTRACT							
Saturation Percentage							
EC_e@ 25°C	(mmhos/cm)	15.0	6.0	3.2	1.8	2.0	1.4
Ca++	(me/1)						
Mg++	(me/1)						
Na+	(me/1)						
K+	(me/1)						
CO_3-	(me/1)						
HCO_3-	(me/1)						
Cl-	(me/1)						
SO_4-	(me/1)						
NO_3-	(me/1)						
SAR	(me/1)			35.0		23.0	
Na	(me/100g)						
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)						
Ca+Mg	(me/1)						
EXCHANGEABLE SODIUM	(percent)						
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)						
NaOAc@pH 8.2							
BORON	(mg/1)						

Table 31
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
WATER AND POWER RESOURCES SERVICE
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC CORE ANALYSIS
DH-78-101 (cont.)

Study Area: Rattlesnake Butte, North Dakota Relief: Stoniness: Parent Material:

Location. Sec.___ Twp.___ Range___ Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Ground Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA			
Laboratory Number		11,707	11,708	11,709	11,710
Sack Number		101-7	101-8	101-9	101-10
Depth (Ft)		122.9-132.6	149.9-165.3	165.3-185.0	185.0-205.2
ALUMINUM	Al				
SILVER	Ag				
ARSENIC	As				
BORON	B	0.8	0.0	0.8	0.7
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd	0.30	0.24	0.06	0.04
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu	14.2	8.4	2.0	1.0
IRON	Fe	98.0	36.4	47.2	70.0
MERCURY	Hg				
LITHIUM	Li				
MANGANESE	Mn	24.0	1.8	3.8	6.4
MOLYBDENUM	Mo				
NICKEL	Ni				
PHOSPHOROUS	P				
LEAD	Pb	6.8	7.0	2.8	2.0
STRONTIUM	Sr				
SELENIUM	Se				
VANADIUM	V				
ZINC	Zn	13.2	13.4	5.4	4.7

LABORATORY DESCRIPTION

DETERMINATION		DATA			
Laboratory Number		11,707	11,708	11,709	11,710
Sack Number		101-7	101-8	101-9	101-10
DEPTH	(Ft)	122.9-132.6	149.9-165.3	165.3-185.0	185.0-205.2
PARTICLE SIZE ANALYSIS	(percent)				
Very Coarse Sand	(2.0-1.0 mm)			0.0	0.5
Coarse Sand	(1.0-0.5 mm)			0.4	1.8
Medium Sand	(0.5-0.25 mm)			9.4	18.9
Fine Sand	(0.25-0.10 mm)			38.4	55.0
Very Fine Sand	(0.10-0.05 mm)			22.3	8.5
TOTAL SAND	(2.0-0.05 mm)	2.1	3.7	70.5	84.7
SILT	(0.05-0.002 mm)	57.0	64.1	14.6	6.3
CLAY	(0.002 mm)	40.9	32.2	14.9	9.0
TEXTURAL CLASS (LAB)		SiC	SiCL	FSL	LFS
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(in/hr)				
6th Hr.		0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	115	60	55	58
MOISTURE RETENTION	(percent)				
1/10 bar					
1/3 bar					
15 bar		28.1	34.5	19.6	11.3
SOIL REACTION-pH					
Paste					
1:5 H_2O		9.7	9.8	10.0	9.9
1:2 0.01 M $CaCl_2$					
ORGANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
Ca CO_3 EQUIVALENT	(percent)				
GYPSUM REQUIREMENT	(me/100g)				
SATURATION EXTRACT					
Saturation Percentage					
EC_e @ 25°C	(mmhos/cm)	1.9	2.	2.9	3.2
Ca++	(me/l)				
Mg++	(me/l)				
Na+	(me/l)				
K+	(me/l)				
CO_3-	(me/l)				
HCO_3-	(me/l)				
Cl-	(me/l)				
SO_4-	(me/l)				
NO_3-	(me/l)				
SAR	(me/l)	56.0		46.0	
Na	(me/100g)				
Ca+Mg	(me/100g)				
1:5 EXTRACT					
EC_5 @ 25°C	(mmhos/cm)				
Ca+Mg	(me/l)				
EXCHANGEABLE SODIUM	(percent)				
ACIDITY					
IN KCL exchange acidity					
Total	(me/100g)				
Al+++	(me/100g)				
CATION EXCHANGE CAPACITY	(me/100g)				
NaOAc@pH 8.2					
BORON	(mg/l)				

Table 31
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
WATER AND POWER RESOURCES SERVICE
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC CORE ANALYSIS
DH-78-102

Study Area: Rattlesnake Butte, North Dakota Relief: Stoniness: Parent Material:

Location. Sec. Twp. Range Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Ground Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (ppm)					
Laboratory Number		11,711	11,712	11,713	11,714	11,715	11,716
Sack Number		102-1	102-2	102-3	102-4	102-5	102-6
Depth (Ft)		0-25.0	25.0-48.7	60.8-83.0	83.0-98.0	98.0-112.8	112.8-129.5
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.1	0.5	1.5	2.4	2.2	0.7
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.16	0.26	0.24	0.22	0.18	0.10
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	2.8	7.6	12.8	8.6	10.8	2.4
IRON	Fe	56.0	46.0	112.0	108.0	74.0	52.0
MERCURY	Hg						
LITHIUM	Li						
MANCANESE	Mn	11.0	11.0	30.0	27.8	13.2	6.8
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	1.4	3.8	3.4	4.0	4.0	2.0
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn						

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number							
Sack Number							
DEPTH	(Ft)	11,711	11,712	11,713	11,714	11,715	11,716
PARTICLE SIZE ANALYSIS	(percent)	102-1	102-2	102-3	102-4	102-5	102-6
Very Coarse Sand	(2.0-1.0 mm)	0-25.0	25.0-48.7	60.8-83.0	83.0-98.0	98.0-112.8	112.8-129.5
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
TOTAL SAND	(2.0-0.05 mm)	16.2	10.3	1.2	4.7	19.3	63.1
SILT	(0.05-0.002 mm)	65.2	53.7	70.6	65.2	49.7	16.5
CLAY	(0.002 mm)	28.6	36.0	28.2	30.1	31.0	20.4
TEXTURAL CLASS (LAB)		SiCL	SiCL	SiCL	SiCL	SiCL	SCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.		0.01	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	45	60	57	104	156	100
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		21.1	26.7	32.4	34.3	42.1	37.3
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.3	8.6	9.5	9.9	9.8	10.1
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)						
SATURATION EXTRACT							
Saturation Percentage							
EC_e@ 25°C	(mmhos/cm)	8.4	7.1	1.9	2.7	2.5	2.3
Ca++	(me/l)						
Mg++	(me/l)						
Na+	(me/l)						
K+	(me/l)						
CO_3-	(me/l)						
HCO_3-	(me/l)						
Cl-	(me/l)						
SO_4-	(me/l)						
NO_3-	(me/l)						
SAR	(me/l)		14.0		42.0		44.0
Na	(me/100g)						
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_e@ 25°C	(mmhos/cm)						
Ca+Mg	(me/l)						
EXCHANGEABLE SODIUM	(percent)						
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)						
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 32
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
WATER AND POWER RESOURCES SERVICE
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC CORE ANALYSIS
DH-78-102 (cont.)

Study Area: Rattlesnake Butte, North Dakota
Location. Sec.____ Twp.____ Range____
Climate:
Land Use:

Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:

Stoniness:
Drainage:
Ground Water:
Land Form:

Parent Material:
Soil Series:
Soil Classification:
Profile Description By: Date:

DETERMINATION		DATA (ppm)				
Laboratory Number		11,717	11,718	11,719	11,720	11,721
Sack Number		102-7	102-8	102-9	102-10	102-11
Depth (Ft)		129.5-159.5	164.3-174.9	174.9-195.0	195.0-217.2	217.7-245.6
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	3.5	1.4	0.9	2.4	1.0
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.36	0.18	0.14	0.32	0.14
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	11.2	10.4	9.2	11.8	3.8
IRON	Fe	94.0	112.0	128.0	118.0	64.0
MERCURY	Hg					
LITHIUM	Li					
MANGANESE	Mn	17.2	19.2	24.6	32.0	7.6
MOLYBDENUM	Mo					
NICKEL	Ni					
PHOSPHOROUS	P					
LEAD	Pb	3.2	3.2	3.8	5.6	1.6
STRONTIUM	Sr					
SELENIUM	Se					
VANADIUM	V					
ZINC	Zn					10.2

DETERMINATION		LABORATORY DESCRIPTION DATA				
Laboratory Number		11,717	11,718	11,719	11,720	11,721
Sack Number		102-7	102-8	102-9	102-10	102-11
DEPTH	(Ft)	129.5-159.5	164.3-174.9	174.9-195.0	195.0-217.7	217.7-245.6
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
TOTAL SAND	(2.0-0.05 mm)	21.4	9.0	3.3	1.4	47.0
SILT	(0.05-0.002 mm)	55.8	66.2	57.6	50.5	33.1
CLAY	(0.002 mm)	22.8	24.8	39.1	48.1	19.9
TEXTURAL CLASS (LAB)		SiL	SiL	SiCL	SiC	L
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.00	0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	92	162	187	78	80
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		32.2	48.1	42.1	30.8	32.9
SOIL REACTION-pH						
Paste						
1:5 H_2O		9.8	10.0	9.5	9.6	9.5
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage						
EC_e @ 25°C	(mmhos/cm)	2.7	1.5	2.7	2.9	5.0
Ca++	(me/l)					
Mg++	(me/l)					
Na+	(me/l)					
K+	(me/l)					
CO3-	(me/l)					
HCO3-	(me/l)					
Cl-	(me/l)					
SO4-	(me/l)					
NO3-	(me/l)					
SAR	(me/l)		28.0			42.0
Na	(me/100g)					
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_e @ 25°C	(mmhos/cm)					
Ca+Mg	(me/l)					
EXCHANGEABLE SODIUM	(percent)					
ACIDITY						
IN KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)					
NaOAc@pH 8.2						
BORON	(mg/l)					

Table 32
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Ceologic Core Analysis

DH-79-103

Study Area: Rattlesnake Butte Relief: Stoniness: Parent Material:

Location. Sec. Twp. Range Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Cround Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (mg/1)					
Laboratory Number		14,280	14,281	14,282	14,283	14,284	14,285
Sack Number		79-103-1	79-103-2	79-103-3	79-103-4	79-103-5	79-103-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	1.6	2.7	1.9	4.1	8.4	5.0
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.14	0.22	0.50	0.32	0.28	0.12
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	3.2	18.0	7.2	21.0	11.0	5.0
IRON	Fe	100.0	222.0	204.0	378.0	104.0	178.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	98.8	36.0	16.0	38.0	12.0	20.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	3.2	5.8	4.2	9.4	14.0	3.4
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	3.2	8.6	9.0	19.0	17.0	5.0

LABORATORY DESCRIPTION							
DETERMINATION		DATA					
Laboratory Number		14,280	14,281	14,282	14,283	14,284	14,285
Sack Number		79-103-1	79-103-2	79-103-3	79-103-4	79-103-5	79-103-6
DEPTH	(Ft)	0.0-17.0	18.5-40.0	40.0-55.0	57.5-79.0	90.0-105.0	105.0-133.7
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.0					0.8
Coarse Sand	(1.0-0.5 mm)	0.1					0.8
Medium Sand	(0.5-0.25 mm)	0.2					4.6
Fine Sand	(0.25-0.10 mm)	30.5					54.3
Very Fine Sand	(0.10-0.05 mm)	28.8					18.8
TOTAL SAND	(2.0-0.05 mm)	59.6	3.7	42.6	22.6	19.1	79.3
SILT	(0.05-0.002 mm)	21.2	57.9	37.0	35.6	54.3	14.7
CLAY	(0.002 mm)	19.2	38.4	20.4	48.8	26.6	6.0
TEXTURAL CLASS (LAB)		FSL	SiCL	L	C	SiL	LFS
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.04	0.00	0.00	0.00	0.00	0.31
24th Hr.		0.02	0.00	0.00	0.00	0.00	0.43
SETTLING VOLUME	(ml)	26	42	86	54	38	18
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.5	8.6	10.0	9.7	9.6	9.0
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
CYPSUM REQUIREMENT	(me/100g)	+0.5	+8.0	+11.4	+13.4	+10.0	0.0
SATURATION EXTRACT							
Saturation Percentage		52.6	86.5	77.2	83.5	53.3	31.6
EC_e@ 25°C	(mmhos/cm)	6.7	8.1	3.4	4.4	3.0	3.4
Ca++	(me/1)	11.47	8.45	0.33	0.38	0.55	3.24
Mg++	(me/1)	21.89	10.95	0.27	0.27	0.45	2.17
Na+	(me/1)	53.13	78.91	36.73	49.40	33.48	33.34
K+	(me/1)	0.54	1.23	0.31	0.42	0.27	0.64
CO_3-	(me/1)	0.00	0.00	0.89	2.86	1.04	0.55
HCO_3-	(me/1)	4.58	5.84	12.79	22.28	20.13	10.13
Cl-	(me/1)	1.72	0.25	0.20	0.31	0.25	0.56
SO_4-	(me/1)	74.74	84.32	23.13	26.13	9.08	34.35
NO_3-	(me/1)						
SAR	(me/1)	13.0	25.0	67.0	87.0	47.0	25.0
Na	(me/100g)	2.79	6.83	2.84	4.12	1.78	1.12
Ca+Mg	(me/100g)	1.73	1.68	0.05	0.05	0.05	0.17
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	1.1	1.6	1.2	1.2	0.5	0.5
Ca+Mg	(me/1)	4.12	4.89	0.53	0.63	0.70	0.38
EXCHANGEABLE SODIUM	(percent)	15.0	25.0	70.0	62.0	52.0	13.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	14.7	20.4	16.2	21.7	16.7	5.9
NaOAc@pH 8.2							
BORON	(mg/1)						

Table 33
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis (cont.)

DH-79-103

Study Area: Rattlesnake Butte Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. ____ Range ____ Elevation: _____ _____ Soil Series: _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Climate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (mg/1)			
Laboratory Number		14,286	14,287	14,288	14,289
Sack Number		79-103-7	79-103-8	79-103-9	79-103-10
Depth					
ALUMINUM	Al				
SILVER	Ag				
ARSENIC	As				
BORON	B	5.2	4.4	2.0	3.0
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd	0.02	0.28	0.22	0.20
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu	11.0	25.0	16.0	16.0
IRON	Fe	120.0	214.0	300.0	292.0
MERCURY	Hg				
LITHIUM	Li				
MANGANESE	Mn	7.4	7.2	20.0	22.0
MOLYBDENUM	Mo				
NICKEL	Ni				
PHOSPHOROUS	P				
LEAD	Pb	4.6	11.0	5.6	5.6
STRONTIUM	Sr				
SELENIUM	Se				
VANADIUM	V				
ZINC	Zn	3.0	11.0	12.0	12.0

LABORATORY DESCRIPTION					
DETERMINATION			DATA			
Laboratory Number			14,286	14,287	14,288	14,289
Sack Number			79-103-7	79-103-8	79-103-9	79-103-10
DEPTH		(Ft)	134.2-140.2	140.2-154.0	154.0-174.7	176.7-194.5
PARTICLE SIZE ANALYSIS		(percent)				
Very Coarse Sand		(2.0-1.0 mm)				0.1
Coarse Sand		(1.0-0.5 mm)				0.2
Medium Sand		(0.5-0.25 mm)				0.4
Fine Sand		(0.25-0.10 mm)				32.5
Very Fine Sand		(0.10-0.05 mm)				21.0
TOTAL SAND		(2.0-0.05 mm)	11.7	10.1	47.0	54.2
SILT		(0.05-0.002 mm)	50.8	49.9	29.3	27.6
CLAY		(0.002 mm)	37.5	40.0	23.7	18.2
TEXTURAL CLASS (LAB)			SiCL	SiCL	L	FSL
BULK DENSITY		(g/cm^3)				
HYDRAULIC CONDUCTIVITY		(in/hr)				
6th Hr.			0.00	0.00	0.00	0.00
24th Hr.			0.00	0.00	0.00	0.00
SETTLING VOLUME		(ml)	58	168	182	102
MOISTURE RETENTION		(percent)				
1/10 bar						
1/3 bar						
15 bar						
SOIL REACTION-pH						
Paste						
1:5 H_2O			9.2	9.9	9.9	10.1
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON		(percent)				
AVAILABLE PHOSPHORUS		(ppm)				
Ca CO_3 EQUIVALENT		(percent)				
GYPSUM REQUIREMENT		(me/100g)	+9.6	+14.0	+9.0	+9.7
SATURATION EXTRACT						
Saturation Percentage			68.1	85.8	116.3	79.6
EC_e @ 25°C		(mmhos/cm)	2.3	5.0	2.5	2.2
Ca++		(me/1)	0.49	0.66	0.22	0.27
Mg++		(me/1)	0.27	0.54	0.09	0.09
Na+		(me/1)	27.40	50.55	25.40	24.92
K+		(me/1)	0.24	0.46	0.16	0.17
CO_3-		(me/1)	1.28	0.00	0.94	0.77
HCO_3-		(me/1)	18.69	14.50	13.58	14.94
Cl-		(me/1)	0.20	0.36	0.16	0.18
SO_4-		(me/1)	7.54	37.27	10.37	8.54
NO_3-		(me/1)				
SAR		(me/1)	44.0	66.0	64.0	59.0
Na		(me/100g)	1.87	4.34	2.95	1.98
Ca+Mg		(me/100g)	0.05	0.11	0.04	0.03
1:5 EXTRACT						
EC_5 @ 25°C		(mmhos/cm)	1.1	1.0	1.3	1.1
Ca+Mg		(me/1)	0.38	0.43	0.42	0.37
EXCHANGEABLE SODIUM		(percent)	45.0	59.0	20.0	71.0
ACIDITY						
IN KCL exchange acidity						
Total		(me/100g)				
Al+++		(me/100g)				
CATION EXCHANGE CAPACITY		(me/100g)	20.3	19.5	17.7	12.0
NaOAc@pH 8.2						
BORON		(mg/1)				

Table 33
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis

DH-79-104

Study Area: Rattlesnake Butte Relief: Stoniness: Parent Material:

Location. Sec. ____ Twp. ____ Range ____ Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Ground Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		14,290	14,291	14,292	14,293	14,294	14,295
Sack Number		79-104-1	79-104-2	79-104-3	79-104-4	79-104-5	79-104-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.3	1.3	1.3	1.1	2.7	3.5
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.08	0.16	0.22	0.12	0.24	0.32
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	12.0	19.0	17.0	11.0	24.0	26.0
IRON	Fe	132.0	182.0	92.0	124.0	262.0	200.0
MERCURY	Hg						
LITHIUM	Li						
MANCANESE	Mn	16.4	28.0	22.0	18.0	50.0	16.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	180.0	12.0	9.4	6.4	11.0	13.0
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	45.4	17.0	18.0	11.0	18.0	23.0

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,290	14,291	14,292	14,293	14,294	14,295
Sack Number		79-104-1	79-104-2	79-104-3	79-104-4	79-104-5	79-104-6
DEPTH	(Ft)	0.0-33.5	33.5-42.2	43.0-54.5	54.5-66.0	68.5-84.0	85.3-94.5
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.4					
Coarse Sand	(1.0-0.5 mm)	3.7					
Medium Sand	(0.5-0.25 mm)	23.0					
Fine Sand	(0.25-0.10 mm)	33.2					
Very Fine Sand	(0.10-0.05 mm)	6.9					
TOTAL SAND	(2.0-0.05 mm)	67.2	3.7	11.4	43.1	19.0	1.7
SILT	(0.05-0.002 mm)	15.3	60.7	66.4	35.7	45.2	61.3
CLAY	(0.002 mm)	17.5	35.7	22.2	21.2	35.8	37.0
TEXTURAL CLASS (LAB)		FSL	SiCL	SiL	L	SiCL	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
SETTLINC VOLUME	(ml)	20	27	26	26	43	56
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.2	7.9	8.4	9.2	9.5	9.6
1:2 0.01 M $CaCl_2$							
ORCANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
CYPSUM REQUIREMENT	(me/100g)	-0.6	-1.1	+1.6	+3.6	+8.2	+11.2
SATURATION EXTRACT							
Saturation Percentage		36.5	59.4	57.7	54.6	64.5	91.3
EC_e@ 25°C	(mmhos/cm)	0.80	2.5	2.1	1.9	2.7	2.2
Ca++	(me/l)	5.00	10.26	4.17	1.04	0.71	0.55
Mg++	(me/l)	1.99	10.76	3.80	0.81	0.45	0.18
Na+	(me/l)	1.87	7.80	15.64	18.03	27.40	23.10
K+	(me/l)	0.23	1.00	0.70	0.48	0.49	0.31
CO_3-	(me/l)	0.00	0.00	0.11	0.09	0.57	0.52
HCO_3-	(me/l)	5.63	4.48	10.90	9.23	13.90	14.91
Cl-	(me/l)	1.48	0.29	0.23	0.19	0.28	0.23
SO_4-	(me/l)	2.08	26.34	9.58	9.79	13.20	6.02
NO_3-	(me/l)						
SAR	(me/l)	1.0	2.4	7.8	19.0	36.0	38.0
Na	(me/100g)	0.07	0.46	0.90	0.98	1.77	2.11
Ca+Mg	(me/100g)	0.25	1.25	0.46	0.10	0.08	0.07
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.2	0.5	0.6	0.5	1.2	0.7
Ca+Mg	(me/l)	1.42	3.50	1.38	0.76	0.76	0.80
EXCHANCEABLE SODIUM	(percent)	1.9	2.5	7.4	21.0	41.0	47.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANCE CAPACITY	(me/100g)	13.1	18.7	22.1	17.0	18.4	22.5
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 34
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis (cont.)
DH-79-104

Study Area: Rattlesnake Butte Relief: Stoniness: Parent Material:
Location. Sec. ___ Twp. ___ Range ___ Elevation: Soil Series:
Slope Aspect: Drainage: Soil Classification:
Climate: Vegetation: Ground Water:
Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (mg/l)	
Laboratory Number		14,296	14,297
Sack Number		79-104-7	79-104-8
Depth			
ALUMINUM	Al		
SILVER	Ag		
ARSENIC	As		
BORON	B	6.6	5.0
BARIUM	Ba		
BERYLLIUM	Be		
CADMIUM	Cd	0.20	0.44
COBALT	Co		
CHROMIUM	Cr		
COPPER	Cu	12.0	16.0
IRON	Fe	116.0	170.0
MERCURY	Hg		
LITHIUM	Li		
MANGANESE	Mn	16.0	32.0
MOLYBDENUM	Mo		
NICKEL	Ni		
PHOSPHOROUS	P		
LEAD	Pb	24.0	14.0
STRONTIUM	Sr		
SELENIUM	Se		
VANADIUM	V		
ZINC	Zn	15.0	17.0

DETERMINATION		LABORATORY DESCRIPTION DATA	
Laboratory Number		14,296	14,297
Sack Number		79-104-7	79-104-8
DEPTH	(Ft)	103.0-111.1	113.3-120.0
PARTICLE SIZE ANALYSIS	(percent)		
Very Coarse Sand	(2.0-1.0 mm)		
Coarse Sand	(1.0-0.5 mm)		
Medium Sand	(0.5-0.25 mm)		
Fine Sand	(0.25-0.10 mm)		
Very Fine Sand	(0.10-0.05 mm)		
TOTAL SAND	(2.0-0.05 mm)	2.7	10.5
SILT	(0.05-0.002 mm)	47.3	66.2
CLAY	(0.002 mm)	50.0	23.3
TEXTURAL CLASS (LAB)		SiL	SiL
BULK DENSITY	(g/cm^3)		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th Hr.		0.02	0.24
24th Hr.		0.00	0.18
SETTLING VOLUME	(ml)	70	90
MOISTURE RETENTION	(percent)		
1/10 bar			
1/3 bar			
15 bar			
SOIL REACTION-pH			
Paste			
1:5 H_2O		9.1	9.5
1:2 0.01 M $CaCl_2$			
ORGANIC CARBON	(percent)		
AVAILABLE PHOSPHORUS	(ppm)		
Ca CO_3 EQUIVALENT	(percent)		
GYPSUM REQUIREMENT	(me/100g)	+15.0	+8.0
SATURATION EXTRACT			
Saturation Percentage		83.5	66.2
EC_e@ 25°C	(mmhos/cm)	4.3	2.9
Ca++	(me/l)	0.88	0.55
Mg++	(me/l)	0.45	0.18
Na+	(me/l)	46.34	29.80
K+	(me/l)	0.53	0.29
CO_3-	(me/l)	0.00	0.00
HCO_3-	(me/l)	24.16	13.01
Cl-	(me/l)	0.27	0.28
SO_4-	(me/l)	24.65	15.68
NO_3-	(me/l)		
SAR	(me/l)	57.0	49.0
Na	(me/100g)	3.87	1.97
Ca+Mg	(me/100g)	0.11	0.05
1:5 EXTRACT			
EC_e @ 25°C	(mmhos/cm)	0.8	0.5
Ca+Mg	(me/l)	0.91	0.70
EXCHANGEABLE SODIUM	(percent)	25.0	35.0
ACIDITY			
IN KCL exchange acidity			
Total	(me/100g)		
Al+++	(me/100g)		
CATION EXCHANGE CAPACITY	(me/100g)	45.0	21.1
NaOAc@pH 8.2			
BORON	(mg/l)		

Table 34
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis
DH-79-105

Study Area: Rattlesnake Butte Relief: Stoniness: Parent Material:
Location. Sec. Twp. Range Elevation: Soil Series:
Slope Aspect: Drainage: Soil Classification:
Climate: Vegetation: Ground Water:
Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		14,298	14,299	14,300	14,301	14,302	14,303
Sack Number		79-105-1	79-105-2	79-105-3	79-105-4	79-105-5	79-105-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.9	1.9	2.1	3.3	2.8	1.9
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.28	0.28	0.26	0.28	0.32	0.26
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	7.0	18.0	21.0	14.0	19.0	21.0
IRON	Fe		92.0	288.0	116.0	404.0	206.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	11.0	20.4	13.0	4.4	60.0	12.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	16.0	7.0	11.0	6.6	7.0	11.0
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	6.0	12.0	7.2	23.0	14.0	9.2

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,298	14,299	14,300	14,301	14,302	14,303
Sack Number		79-105-1	79-105-2	79-105-3	79-105-4	79-105-5	79-105-6
DEPTH	(Ft)	0.0-20.5	20.5-29.5	30.7-39.7	49.2-57.1	58.1-65.1	67.8-77.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
TOTAL SAND	(2.0-0.05 mm)	6.3	10.0	0.9	15.1	20.0	7.6
SILT	(0.05-0.002 mm)	62.9	56.5	67.2	61.7	43.6	64.8
CLAY	(0.002 mm)	30.8	33.5	31.9	23.2	36.4	27.6
TEXTURAL CLASS (LAB)		SiCL	SiCL	SiCL	SiL	SiCL	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.16	1.26	0.00	0.00	0.00	0.00
24th Hr.		0.12	1.26	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	54	132	54	46	76	68
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		9.0	9.5	9.4	9.1	9.7	10.0
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+2.0	+9.0	+7.2	+5.0	+9.2	+11.5
SATURATION EXTRACT							
Saturation Percentage		82.0	114.5	81.3	67.1	102.3	83.6
EC_e@ 25°C	(mmhos/cm)	7.5	3.3	2.9	4.0	2.1	2.8
Ca++	(me/l)	15.09	0.61	0.66	0.82	0.60	0.38
Mg++	(me/l)	15.92	0.90	0.63	1.0	0.27	0.36
Na+	(me/l)	62.60	32.28	28.17	39.89	22.19	31.04
K+	(me/l)	0.74	0.37	0.48	0.48	0.21	0.34
CO_3-	(me/l)	0.00	0.00	0.00	0.11	0.95	0.87
HCO_3-	(me/l)	3.36	7.76	8.11	9.24	13.81	15.39
Cl-	(me/l)	0.21	0.19	0.20	0.31	0.17	0.24
SO_4-	(me/l)	89.53	28.73	20.40	35.81	7.22	13.66
NO_3-	(me/l)						
SAR	(me/l)	16.0	37.0	35.0	42.0	34.0	51.0
Na	(me/100g)	5.13	3.70	2.29	2.67	2.27	2.59
Ca+Mg	(me/100g)	0.23	0.17	0.10	0.13	0.09	0.06
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	2.0	1.0	1.0	0.6	0.8	0.7
Ca+Mg	(me/l)	2.83	2.02	0.90	0.47	0.63	0.75
EXCHANGEABLE SODIUM	(percent)	9.8	36.0	37.0	35.0	52.0	63.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	22.1	19.8	17.7	12.9	19.1	18.3
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 35
Sheet 1 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis (cont.)

DH-79-105

Study Area: Rattlesnake Butte Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. _____ Range _____ Elevation: _____ _____ Soil Series: _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Climate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (mg/l)					
Laboratory Number		14,304	14,305	14,306	14,307	14,308	14,309
Sack Number		79-105-7	79-105-8	79-105-9	79-105-10	79-105-11	79-105-12
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	1.3	0.9	1.1	1.3	1.7	2.0
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.10	0.06	0.08	0.10	0.28	0.22
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	7.4	4.0	4.4	4.4	23.0	20.0
IRON	Fe	148.0	224.0	264.0	264.0	294.0	336.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	8.0	8.0	10.0	10.0	14.0	24.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	5.8	4.8	4.6	5.6	10.0	9.8
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	7.6	7.6	6.8	6.8	15.0	15.0

DETERMINATION		LABORATORY DESCRIPTION DATA					
Laboratory Number		14,304	14,305	14,306	14,307	14,308	14,309
Sack Number		79-105-7	79-105-8	79-105-9	79-105-10	79-105-11	79-105-12
DEPTH	(Ft)	77.0-95.0	95.0-115.0	115.0-135.0	135.0-144.6	144.9-159.4	159.4-172.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)		0.6	0.2	0.5		
Coarse Sand	(1.0-0.5 mm)		4.2	0.8	1.5		
Medium Sand	(0.5-0.25 mm)		3.1	3.5	11.6		
Fine Sand	(0.25-0.10 mm)		37.9	54.5	60.6		
Very Fine Sand	(0.10-0.05 mm)		25.2	21.1	7.4		
TOTAL SAND	(2.0-0.05 mm)	38.6	71.0	80.1	81.6	23.0	17.7
SILT	(0.05-0.002 mm)	43.8	17.0	4.1	8.7	46.6	49.2
CLAY	(0.002 mm)	17.6	12.0	15.8	9.7	30.4	33.1
TEXTURAL CLASS (LAB)		L	FSL	FSL	LFS	CL	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	83	78	93	53	56	88
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		10.1	10.2	10.0	10.1	9.9	9.9
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+9.0	+7.4	+7.1	+6.9	+14.3	+11.8
SATURATION EXTRACT							
Saturation Percentage		91.9	70.2	66.7	49.7	93.1	110.0
EC_e @ 25° C	(mmhos/cm)	2.0	2.1	2.5	3.0	2.8	2.0
Ca++	(me/l)	0.16	0.27	0.16	0.22	0.22	0.16
Mg++	(me/l)	0.09	0.09	0.09	0.18	0.18	0.09
Na+	(me/l)	20.90	21.19	25.97	30.80	29.37	20.57
K+	(me/l)	0.19	0.18	0.20	0.83	0.28	0.20
CO3-	(me/l)	0.53	0.16	0.19	1.39	0.15	0.33
HCO3-	(me/l)	12.43	10.99	10.15	11.57	13.93	11.94
Cl-	(me/l)	0.14	0.19	0.34	0.36	0.29	0.13
SO4-	(me/l)	7.22	8.85	14.57	16.45	13.64	7.29
NO3-	(me/l)						
SAR	(me/l)	50.0	72.0	68.0	65.0	57.0	69.0
Na	(me/100g)	1.92	1.49	1.73	1.51	2.23	2.26
Ca+Mg	(me/100g)	0.02	0.03	0.02	0.02	0.04	0.03
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.7	0.7	0.6	0.6	0.8	0.8
Ca+Mg	(me/l)	0.86	0.96	0.92	0.50	0.62	0.91
EXCHANGEABLE SODIUM	(percent)	69.0	67.0	70.0	69.0	59.0	57.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	13.8	9.5	9.6	9.0	18.6	19.0
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 35
Sheet 2 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA

Geologic Core Analysis (cont.)

DH-79-105

Study Area: _____ Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. _____ Range _____ Elevation: _____ Soil Series: _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Climate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (mg/l)			
Laboratory Number		14,310	14,311	14,312	14,313
Sack Number		79-105-13	79-105-14	79-105-15	79-105-16
Depth					
ALUMINUM	Al				
SILVER	Ag				
ARSENIC	As				
BORON	B	1.6	1.9	2.2	1.7
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd	0.24	0.22	0.22	0.12
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu	22.0	20.0	24.0	15.0
IRON	Fe	168.0	310.0	384.0	158.0
MERCURY	Hg				
LITHIUM	Li				
MANGANESE	Mn	6.2	18.0	38.0	8.0
MOLYBDENUM	Mo				
NICKEL	Ni				
PHOSPHOROUS	P				
LEAD	Pb	16.0	9.0	10.0	9.4
STRONTIUM	Sr				
SELENIUM	Se				
VANADIUM	V				
ZINC	Zn	11.0	14.0	17.0	9.0

LABORATORY DESCRIPTION					
DETERMINATION		DATA			
Laboratory Number		14,310	14,311	14,312	14,313
Sack Number		79-105-13	79-105-14	79-105-15	79-105-16
DEPTH	(Ft)	172.4-180.5	180.5-192.5	195.5-223.0	223.0-244.5
PARTICLE SIZE ANALYSIS	(percent)				
Very Coarse Sand	(2.0-1.0 mm)				
Coarse Sand	(1.0-0.5 mm)				
Medium Sand	(0.5-0.25 mm)				
Fine Sand	(0.25-0.10 mm)				
Very Fine Sand	(0.10-0.05 mm)				
TOTAL SAND	(2.0-0.05 mm)	40.8	18.9	0.8	15.5
SILT	(0.05-0.002 mm)	22.4	46.8	55.4	58.7
CLAY	(0.002 mm)	37.0	34.3	43.8	25.8
TEXTURAL CLASS (LAB)		CL	SiCL	SiC	SiL
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(in/hr)				
6th Hr.		0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	80	262	328	220
MOISTURE RETENTION	(percent)				
1/10 bar					
1/3 bar					
15 bar					
SOIL REACTION-pH					
Paste					
1:5 H_2O		9.8	9.9	9.9	10.1
1:2 0.01 M $CaCl_2$					
ORGANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
Ca CO_3 EQUIVALENT	(percent)				
GYPSUM REQUIREMENT	(me/100g)	+17.1	+14.4	+13.1	+14.6
SATURATION EXTRACT					
Saturation Percentage		87.6	158.9	161.5	149.7
EC_e@ 25°C	(mmhos/cm)	3.5	1.8	1.7	1.3
Ca++	(me/l)	0.27	0.16	0.16	0.11
Mg++	(me/l)	0.27	0.09	0.09	0.09
Na+	(me/l)	35.92	18.65	17.27	13.53
K+	(me/l)	0.26	0.19	0.21	0.12
CO_3-	(me/l)	0.00	0.27	0.34	0.19
HCO_3-	(me/l)	12.52	10.84	12.78	10.59
Cl-	(me/l)	0.28	0.20	0.10	0.11
SO_4-	(me/l)	19.57	7.45	3.96	3.12
NO_3-	(me/l)				
SAR	(me/l)	69.0	52.0	48.0	43.0
Na	(me/100g)	3.15	2.96	2.76	2.03
Ca+Mg	(me/100g)	0.04	0.04	0.04	0.03
1:5 EXTRACT					
EC_5 @ 25°C	(mmhos/cm)	1.0	0.9	0.8	0.8
Ca+Mg	(me/l)	0.81	1.88	1.73	1.53
EXCHANGEABLE SODIUM	(percent)	60.0	57.0	69.0	64.0
ACIDITY					
IN KCL exchange acidity					
Total	(me/100g)				
Al+++	(me/100g)				
CATION EXCHANGE CAPACITY	(me/100g)	22.7	21.9	24.0	21.0
NaOAc@pH 8.2					
BORON	(mg/l)				

Table 35
Sheet 3 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis

DH-79-106

Study Area: Rattlesnake Butte Relief: Stoniness: Parent Material:

Location. Sec. Twp. Range Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Ground Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		14,314	14,315	14,316	14,317	14,318	14,319
Sack Number		79-106-1	79-106-2	79-106-3	79-106-4	79-106-5	79-106-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	1.6	0.6	1.9	1.9	1.9	2.4
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.16	0.12	0.24	0.22	0.32	0.24
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	6.0	6.4	22.0	23.0	25.0	28.0
IRON	Fe	138.0	120.0	326.0	304.0	248.0	206.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	11.0	15.0	52.0	28.0	18.0	8.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHORUS	P						
LEAD	Pb	9.0	4.8	11.0	8.8	9.4	11.0
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	4.4	1.8	18.0	15.0	14.0	12.0

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,314	14,415	14,316	14,317	14,318	14,319
Sack Number		79-106-1	79-106-2	79-106-3	79-106-4	79-106-5	79-106-6
DEPTH	(Ft)	0.0-22.0	23.5-44.5	44.5-63.0	68.0-80.0	80.0-96.5	108.2-118.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
TOTAL SAND	(2.0-0.05 mm)	11.8	1.0	1.0	15.9	9.9	4.9
SILT	(0.05-0.002 mm)	48.8	61.7	55.0	51.2	58.0	48.0
CLAY	(0.002 mm)	39.4	37.3	44.0	32.9	32.1	47.1
TEXTURAL CLASS (LAB)		SiCL	SiCL	SiC	SiCL	SiCL	SiC
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.04	0.00	0.00	0.00	0.00	0.00
24th Hr.		0.02	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	29	50	86	135	180	96
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.0	8.8	9.5	9.9	9.8	9.7
1:2 0.01 M $CaCl_2$							
ORCANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
CYPSUM REQUIREMENT	(me/100g)	-8.8	+2.2	+7.6	+11.9	+12.5	+12.0
SATURATION EXTRACT							
Saturation Percentage		65.3	85.6	116.9	128.3	129.3	102.8
EC_e@ 25°C	(mmhos/cm)	8.3	6.4	3.5	2.0	1.7	2.3
Ca++	(me/l)	21.85	7.03	0.77	0.22	0.22	0.27
Mg++	(me/l)	48.76	12.21	1.00	0.18	0.18	0.18
Na+	(me/l)	41.03	45.77	33.81	19.99	17.41	22.81
K+	(me/l)	0.82	1.11	0.62	0.24	0.20	0.24
CO_3-	(me/l)	0.00	0.00	0.00	0.00	0.13	0.14
HCO_3-	(me/l)	3.03	2.54	9.09	12.24	12.73	11.09
Cl-	(me/l)	0.29	0.22	0.32	0.19	0.16	0.29
SO_4-	(me/l)	57.0	57.88	28.73	7.62	3.85	9.99
NO_3-	(me/l)						
SAR	(me/l)	6.9	15.0	36.0	45.0	39.0	48.0
Na	(me/100g)	2.68	3.92	3.95	2.56	2.25	2.34
Ca+Mg	(me/100g)	4.61	1.65	0.21	0.05	0.05	0.05
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	3.6	1.6	1.0	0.8	0.8	0.8
Ca+Mg	(me/l)	20.75	1.67	0.83	1.14	2.01	0.85
EXCHANGEABLE SODIUM	(percent)	7.2	9.5	31.0	44.0	46.0	48.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	23.1	26.5	20.1	22.9	22.2	19.6
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 36
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA

Geologic Core Analysis (cont.)

DH-79-106

Study Area: Rattlesnake Butte Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. ____ Range ____ Elevation: _____ _____ Soil Series: _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Climate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (mg/l)				
Laboratory Number		14,320	14,321	14,322	14,323	14,324
Sack Number		79-106-7	79-106-8	79-106-9	79-106-10	79-106-11
Depth						
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	2.4	1.9	1.1	0.9	2.8
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.22	0.06	0.02	0.02	0.24
COBALT	Co					
GHROMIUM	Cr					
COPPER	Cu	19.0	9.2	1.8	1.4	14.0
IRON	Fe	382.0	136.0	132.0	122.0	198.0
MERCURY	Hg					
LITHIUM	Li					
MANGANESE	Mn	32.0	9.0	5.2	4.2	11.0
MOLYBDENUM	Mo					
NICKEL	Ni					
PHOSPHOROUS	P					
LEAD	Pb	9.8	7.0	4.6	4.6	8.6
STRONTIUM	Sr					
SELENIUM	Se					
VANADIUM	V					
ZINC	Zn	15.0	6.0	2.2	1.6	10.0

DETERMINATION		LABORATORY DESCRIPTION DATA				
Laboratory Number		14,320	14,321	14,322	14,323	14,324
Sack Number		79-106-7	79-106-8	79-106-9	79-106-10	79-106-11
DEPTH	(Ft)	118.0-129.5	129.7-146.7	149.6-169.0	169.0-198.7	208.2-224.5
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)			0.1	0.7	
Coarse Sand	(1.0-0.5 mm)			0.2	0.4	
Medium Sand	(0.5-0.25 mm)			0.5	0.3	
Fine Sand	(0.25-0.10 mm)			55.1	54.4	
Very Fine Sand	(0.10-0.05 mm)			23.5	22.9	
TOTAL SAND	(2.0-0.05 mm)	10.5	17.9	79.4	78.7	6.6
SILT	(0.05-0.002 mm)	58.2	62.7	10.7	16.1	66.2
CLAY	(0.002 mm)	31.3	19.4	9.9	5.2	27.2
TEXTURAL CLASS (LAB)		SiCL	SiL	FSL	LFS	SiCL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.00	0.00	0.01	0.02	0.00
24th Hr.		0.00	0.00	0.01	0.02	0.00
SETTLING VOLUME	(ml)	78	112	24	26	55
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar						
SOIL REACTION-pH						
Paste						
1:5 H_2O		9.9	10.1	10.0	10.1	9.5
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	+8.4	+6.2	+2.8	+0.8	+8.0
SATURATION EXTRACT						
Saturation Percentage		101.9	74.7	33.3	31.9	75.5
EC_e@ 25° C	(mmhos/cm)	1.9	1.7	2.4	2.7	2.9
Ca++	(me/1)	0.22	0.27	0.55	0.55	0.33
Mg++	(me/1)	0.18	0.18	0.27	0.27	0.36
Na+	(me/1)	19.32	17.17	24.01	27.12	30.13
K+	(me/1)	0.22	0.18	0.29	0.72	0.33
CO_3-	(me/1)	0.32	0.00	0.00	0.00	0.72
HCO_3-	(me/1)	12.94	9.71	9.73	9.64	12.96
Cl-	(me/1)	0.21	0.19	0.32	0.32	0.30
SO_4-	(me/1)	5.16	6.60	13.01	16.24	14.62
NO_3-	(me/1)					
SAR	(me/1)	43.0	36.0	37.0	42.0	51.0
Na	(me/100g)	1.97	1.28	0.80	0.87	2.27
Ca+Mg	(me/100g)	0.04	0.03	0.03	0.03	0.05
1:5 EXTRACT						
EC_5@ 25°C	(mmhos/cm)	0.6	0.5	0.4	0.4	0.5
Ca+Mg	(me/1)	0.87	0.68	0.29	0.59	1.16
EXCHANGEABLE SODIUM	(percent)	44.0	45.0	52.0	47.0	
ACIDITY						
IN KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	15.2	12.0	4.0	3.9	
NaOAc@pH 8.2						
BORON	(mg/l)					

Table 36
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA

Geologic Core Analysis

DH-79-107

Study Area: Rattlesnake Butte | Relief: | Stoniness: | Parent Material:

Location. Sec. ____ Twp. ____ Range ____ | Elevation: | | Soil Series:

Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: | Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		14,325	14,326	14,327	14,328	14,329	14,330
Sack Number		79-107-1	79-107-2	79-107-3	79-107-4	79-107-5	79-107-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.5	0.9	1.3	2.0	2.2	2.0
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.06	0.14	0.14	0.16	0.10	0.12
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	13.0	16.0	18.0	19.0	16.0	13.0
IRON	Fe	94.0	206.0	166.0	222.0	306.0	122.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	14.8	48.0	24.0	28.0	54.0	8.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	210.0	7.6	7.2	7.6	10.0	7.4
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	36.2	9.8	8.0	10.0	11.0	8.8

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,325	14,326	14,327	14,328	14,329	14,330
Sack Number		79-107-1	79-107-2	79-107-3	79-107-4	79-107-5	79-107-6
DEPTH	(Ft)	0.0-19.2	19.7-40.0	40.0-52.8	52.8-65.8	65.8-80.0	80.0-96.2
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.4					
Coarse Sand	(1.0-0.5 mm)	0.9					
Medium Sand	(0.5-0.25 mm)	11.7					
Fine Sand	(0.25-0.10 mm)	47.4					
Very Fine Sand	(0.10-0.05 mm)	11.1	21.2	21.2	27.2	1.1	14.6
TOTAL SAND	(2.0-0.05 mm)	71.5	16.7	56.2	50.7	62.3	60.4
SILT	(0.05-0.002 mm)	14.3	62.1	22.6	22.1	36.6	25.0
CLAY	(0.002 mm)	14.2					
TEXTURAL CLASS (LAB)		FSL	C	SiL	SiL	SiCL	SiL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.63	0.08	0.06	0.02	0.00	0.00
24th Hr.		0.59	0.08	0.06	0.01	0.00	0.00
SETTLING VOLUME	(ml)	21	27	21	26	45	50
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.6	8.2	8.5	9.0	9.6	9.9
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-0.4	-0.9	+1.7	+3.4	+6.4	+13.5
SATURATION EXTRACT							
Saturation Percentage		38.8	56.2	58.7	59.0	78.0	72.0
EC_e@ 25°C	(mmhos/cm)	1.0	4.2	4.1	4.1	2.9	2.6
Ca++	(me/1)	3.84	17.24	8.89	5.27	0.49	0.27
Mg++	(me/1)	3.35	20.17	9.23	4.98	0.45	0.18
Na+	(me/1)	2.87	17.84	28.50	35.30	28.41	27.17
K+	(me/1)	0.23	1.40	1.42	1.15	0.57	0.31
CO_3-	(me/1)	0.00	0.00	0.03	0.27	0.15	0.52
HCO_3-	(me/1)	5.53	6.33	7.91	9.59	10.12	14.33
Cl-	(me/1)	0.56	0.37	0.32	0.39	0.26	0.20
SO_4-	(me/1)	3.60	46.85	37.06	31.23	15.72	9.47
NO_3-	(me/1)						
SAR	(me/1)	1.5	4.1	9.5	16.0	41.0	57.0
Na	(me/100g)	0.11	1.00	1.67	2.08	2.22	1.96
Ca+Mg	(me/100g)	0.28	2.10	1.06	0.60	0.08	0.03
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.2	0.7	0.7	0.7	0.7	0.8
Ca+Mg	(me/1)	1.43	4.47	1.67	0.87	0.53	1.23
EXCHANGEABLE SODIUM	(percent)	16.0	13.0	17.0	14.0	37.0	56.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	11.8	18.6	18.9	18.7	14.9	19.3
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 37
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis (cont.)

DH-79-107

Study Area: Rattlesnake Butte Relief: Stoniness: Parent Material:

Location. Sec. Twp. Range Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Ground Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		14,331	14,332	14,333	14,334	14,335	14,336
Sack Number		79-107-7	79-107-8	79-107-9	79-107-10	79-107-11	79-107-12
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	3.5	3.3	3.1	4.5	3.9	1.4
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.24	0.24	0.26	0.18	0.48	0.06
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	26.0	25.0	27.0	20.0	35.0	7.6
IRON	Fe	340.0	350.0	352.0	372.0	156.0	112.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	40.0	25.2	46.0	30.2	14.0	6.2
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	11.0	11.0	13.0	10.0	15.0	6.2
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	17.0	17.0	16.0	17.0	27.0	5.2

LABORATORY DESCRIPTION							
DETERMINATION		DATA					
Laboratory Number		14,331	14,332	14,333	14,334	14,335	14,336
Sack Number		79-107-7	79-107-8	79-107-9	79-107-10	79-107-11	79-107-12
DEPTH	(Ft)	97.8-120.0	120.0-138.7	149.3-166.5	166.5-181.1	183.5-187.2	194.7-213.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)					0.6	
Coarse Sand	(1.0-0.5 mm)					8.0	
Medium Sand	(0.5-0.25 mm)					59.3	
Fine Sand	(0.25-0.10 mm)					9.8	
Very Fine Sand	(0.10-0.05 mm)	16.4	14.8	11.7	13.8	77.7	7.2
TOTAL SAND	(2.0-0.05 mm)	48.9	52.2	51.5	15.8	6.9	58.3
SILT	(0.05-0.002 mm)	34.7	33.0	36.8	70.4	15.4	34.5
CLAY	(0.002 mm)						
TEXTURAL CLASS (LAB)		SiCL	SiCL	SiCL	C	FSL	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	76	88	70	80	50	31
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		9.8	9.8	9.6	9.9	9.4	10.2
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+14.2	+15.1	+13.3	+12.1	+19.2	+7.9
SATURATION EXTRACT							
Saturation Percentage		101.2	107.5	88.0	102.2	73.3	39.0
EC_e@ 25 °C	(mmhos/cm)	2.6	2.6	3.1	2.4	5.2	2.9
Ca++	(me/l)	0.27	0.22	0.38	0.27	0.55	0.55
Mg++	(me/l)	0.18	0.09	0.18	0.09	0.63	0.27
Na+	(me/l)	28.27	28.31	32.81	25.40	57.87	32.62
K+	(me/l)	0.30	0.26	0.30	0.22	0.45	0.12
CO_3-	(me/l)	1.08	0.19	0.63	0.91	1.55	0.66
HCO_3-	(me/l)	19.31	20.60	17.24	16.84	33.73	18.46
Cl-	(me/l)	0.16	0.16	0.28	0.18	0.21	0.29
SO_4-	(me/l)	6.25	5.68	10.97	5.87	18.57	10.83
NO_3-	(me/l)						
SAR	(me/l)	60.0	70.0	62.0	60.0	75.0	51.0
Na	(me/100g)	2.85	3.04	2.89	2.60	4.24	1.27
Ca+Mg	(me/100g)	0.05	0.03	0.05	0.04	0.09	0.03
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.9	0.9	0.9	0.9	1.2	0.5
Ca+Mg	(me/l)	0.25	0.57	0.61	0.52	0.83	0.32
EXCHANGEABLE SODIUM	(percent)	60.0	61.0	58.0	63.0		77.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	22.8	22.8	19.7	17.5		17.5
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 37
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA

Geologic Core Analysis

DH-79-108

Study Area: Rattlesnake Butte | Relief: | Stoniness: | Parent Material:

Location. Sec. ____ Twp. ____ Range ____ | Elevation: | | Soil Series:

Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: | Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		14,337	14,338	14,339	14,340	14,341	14,342
Sack Number		79-108-1	79-108-2	79-108-3	79-108-4	79-108-5	79-108-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.9	0.4	2.0	1.5	1.3	0.9
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.18	0.12	0.14	0.16	0.04	0.04
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	10.0	5.8	26.0	16.0	3.4	4.2
IRON	Fe	92.0	134.0	220.0	134.0	200.0	190.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	17.0	29.0	30.0	7.2	10.0	9.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	30.0	6.2	11.0	8.8	3.6	4.2
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	6.8	2.8	9.4	5.2	3.8	3.8

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,337	14,338	14,339	14,340	14,341	14,342
Sack Number		79-108-1	79-108-2	79-108-3	79-108-4	79-108-5	79-108-6
DEPTH	(Ft)	0.0-20.0	21.0-36.0	37.0-47.7	48.9-63.7	63.7-84.0	84.0-103.8
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)					0.1	0.1
Coarse Sand	(1.0-0.5 mm)					4.5	4.0
Medium Sand	(0.5-0.25 mm)					32.4	25.3
Fine Sand	(0.25-0.10 mm)					39.2	43.8
Very Fine Sand	(0.10-0.05 mm)					9.1	8.9
TOTAL SAND	(2.0-0.05 mm)	7.3	11.3	4.4	12.1	85.3	82.1
SILT	(0.05-0.002 mm)	56.5	39.3	64.8	62.3	4.8	10.5
CLAY	(0.002 mm)	36.2	49.4	30.8	25.6	9.9	7.4
TEXTURAL CLASS (LAB)		SiCL	C	SiCL	SiL	LS	LS
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	70	215	85	50	48	45
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.5	9.3	9.7	9.9	10.0	10.0
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+4.3	+14.7	+14.2	+14.2	+6.5	+4.7
SATURATION EXTRACT							
Saturation Percentage		93.0	109.4	93.8	75.5	51.6	39.9
EC_e@ 25°C	(mmhos/cm)	10.7	2.7	3.7	3.2	3.5	3.0
Ca++	(me/1)	20.53	0.27	0.27	0.44	0.22	0.22
Mg++	(me/1)	20.98	0.27	0.27	0.27	0.09	0.27
Na+	(me/1)	91.35	26.40	38.17	34.87	36.30	31.33
K+	(me/1)	11.0	0.23	0.39	0.27	0.22	0.26
CO_3-	(me/1)	0.00	0.00	15.12	21.90	16.90	17.16
HCO_3-	(me/1)	2.56	5.28	14.90	20.70	16.36	16.11
Cl-	(me/1)	0.35	0.24	0.24	0.30	0.26	0.28
SO_4-	(me/1)	131.17	18.63	20.55	11.24	17.80	13.66
NO_3-	(me/1)						
SAR	(me/1)	21.0	51.0	73.0	59.0	92.0	63.0
Na	(me/100g)	8.90	2.89	3.58	2.63	1.51	1.25
Ca+Mg	(me/100g)	0.35	0.06	0.06	0.05	0.05	0.02
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	3.4	1.4	1.1	0.9	0.6	0.5
Ca+Mg	(me/1)	7.85	1.13	0.99	0.56	1.73	0.71
EXCHANGEABLE SODIUM	(percent)	19.0	54.0	32.0	69.0	70.0	56.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	26.1	25.3	41.3	19.6	8.4	9.1
NaOAc@pH 8.2							
BORON	(mg/1)						

Table 38
Sheet 1 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis (cont.)

DH-79-108

Study Area: Rattlesnake Butte Relief: Stoniness: Parent Material:

Location. Sec. Twp. Range Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Ground Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (mg/1)					
Laboratory Number		14,343	14,344	14,345	14,346	14,347	14,348
Sack Number		79-108-7	79-108-8	79-108-9	79-108-10	79-108-11	79-108-12
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	2.1	2.8	2.2	6.7	2.8	4.4
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.12	0.24	0.24	0.20	0.04	0.10
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	14.0	19.0	27.0	13.0	5.0	2.6
IRON	Fe	240.0	292.0	354.0	366.0	40.0	88.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	36.0	42.0	55.8	86.0	4.0	8.8
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	10.0	9.2	10.0	9.6	6.2	4.0
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	11.0	11.0	20.0	12.0	3.2	6.8

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,343	14,344	14,345	14,346	14,347	14,348
Sack Number		79-108-7	79-108-8	79-108-9	79-108-10	79-108-11	79-108-12
DEPTH	(Ft)	114.7-130.0	130.0-142.0	142.0-147.0	148.5-158.9	158.9-170.0	170.0-192.2
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						0.2
Coarse Sand	(1.0-0.5 mm)						0.5
Medium Sand	(0.5-0.25 mm)						5.2
Fine Sand	(0.25-0.10 mm)						31.6
Very Fine Sand	(0.10-0.05 mm)						21.6
TOTAL SAND	(2.0-0.05 mm)	7.3	2.8	3.5	3.1	13.5	59.1
SILT	(0.05-0.002 mm)	65.9	70.5	19.8	50.5	57.5	25.9
CLAY	(0.002 mm)	31.8	26.7	76.7	46.4	29.0	15.0
TEXTURAL CLASS (LAB)		SiCL	SiL	C	SiL	SiCL	FSL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	36.0	55.0	100.0	95.0	67.0	48.0
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		9.7	9.6	9.8	9.6	10.1	8.8
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+4.7	+9.7	+12.8	+14.3	+11.3	+6.2
SATURATION EXTRACT							
Saturation Percentage		57.4	78.6	113.5	94.3	82.5	46.6
EC_e @ 25 °C	(mmhos/cm)	2.3	3.7	2.3	3.0	2.3	5.0
Ca++	(me/1)	0.33	0.38	0.22	0.27	0.16	0.55
Mg++	(me/1)	0.36	0.18	0.09	0.18	0.09	0.45
Na+	(me/1)	24.15	37.35	24.53	32.14	24.15	48.93
K+	(me/1)	0.34	0.33	0.23	0.29	0.15	0.37
CO3-	(me/1)	14.78	0.00	0.00	0.80	0.09	0.00
HCO3-	(me/1)	14.75	13.39	15.86	21.54	13.58	4.69
Cl-	(me/1)	0.25	0.56	0.30	0.14	0.11	0.47
SO4-	(me/1)	7.25	21.44	7.04	6.87	9.81	46.01
NO3-	(me/1)						
SAR	(me/1)	41.0	71.0	62.0	68.0	68.0	69.0
Na	(me/100g)	1.39	2.94	2.78	3.03	1.99	2.28
Ca+Mg	(me/100g)	0.04	0.04	0.04	0.05	0.02	0.05
1:5 EXTRACT							
EC_e @ 25°C	(mmhos/cm)	0.5	0.9	0.8	0.9	0.6	0.6
Ca+Mg	(me/1)	0.96	0.59	0.75	0.73	0.41	0.55
EXCHANGEABLE SODIUM	(percent)	39.0	59.0	60.0	49.0	74.0	26.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	13.3	15.0	17.4	20.8	15.4	22.4
NaOAc@pH 8.2							
BORON	(mg/1)						

Table 38
Sheet 2 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA

Ceologic Core Analysis (cont.)

DH-79-108

Study Area: Rattlesnake Butte Relief: Stoniness: Parent Material:

Location. Sec. Twp. Range Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Ground Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (mg/1)		
Laboratory Number		14,349	14,350	14,351
Sack Number		79-108-13	79-108-14	79-108-15
Depth				
ALUMINUM	Al			
SILVER	Ag			
ARSENIC	As			
BORON	B	2.2	2.0	3.1
BARIUM	Ba			
BERYLLIUM	Be			
CADMIUM	Cd	0.06	0.06	0.22
COBALT	Co			
CHROMIUM	Cr			
COPPER	Cu	3.0	8.8	15.0
IRON	Fe	110.0	82.0	110.0
MERCURY	Hg			
LITHIUM	Li			
MANCANESE	Mn	6.0	6.0	4.0
MOLYBDENUM	Mo			
NICKEL	Ni			
PHOSPHOROUS	P			
LEAD	Pb	4.4	9.4	11.0
STRONTIUM	Sr			
SELENIUM	Se			
VANADIUM	V			
ZINC	Zn	3.4	3.0	8.8

DETERMINATION		LABORATORY DESCRIPTION DATA		
Laboratory Number		14,349	14,350	14,351
Sack Number		79-108-13	79-108-14	79-108-15
DEPTH	(Ft)	194.9-201.3	202.5-213.3	220.5-234.5
PARTICLE SIZE ANALYSIS	(percent)			
Very Coarse Sand	(2.0-1.0 mm)	0.1	0.2	
Coarse Sand	(1.0-0.5 mm)	0.8	0.4	
Medium Sand	(0.5-0.25 mm)	2.7	0.9	
Fine Sand	(0.25-0.10 mm)	52.1	45.6	
Very Fine Sand	(0.10-0.05 mm)	11.9	14.9	
TOTAL SAND	(2.0-0.05 mm)	67.6	62.0	6.2
SILT	(0.05-0.002 mm)	15.6	18.6	55.6
CLAY	(0.002 mm)	16.8	19.4	38.2
TEXTURAL CLASS (LAB)		FSL	FSL	SiCL
BULK DENSITY	(g/cm^3)			
HYDRAULIC CONDUCTIVITY	(in/hr)			
6th Hr.		0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00
SETTLINC VOLUME	(ml)	106	72	80
MOISTURE RETENTION	(percent)			
1/10 bar				
1/3 bar				
15 bar				
SOIL REACTION-pH				
Paste				
1:5 H_2O		10.2	10.1	9.7
1:2 0.01 M $CaCl_2$				
ORCANIC CARBON	(percent)			
AVAILABLE PHOSPHORUS	(ppm)			
Ca CO_3 EQUIVALENT	(percent)			
CYPSUM REQUIREMENT	(me/100g)	+10.3	+9.7	+13.9
SATURATION EXTRACT				
Saturation Percentage		72.7	59.4	95.7
EC_e@ 25° C	(mmhos/cm)	2.5	2.8	2.4
Ca++	(me/1)	0.22	0.44	0.33
Mg++	(me/1)	0.09	0.18	0.09
Na+	(me/1)	26.35	31.27	26.35
K+	(me/1)	0.14	0.17	0.18
CO_3-	(me/1)	0.82	0.62	0.00
HCO_3-	(me/1)	16.67	22.30	17.80
Cl-	(me/1)	0.11	0.14	0.17
SO_4-	(me/1)	8.48	7.35	5.84
NO_3-	(me/1)			
SAR	(me/1)	67.0	56.0	58.0
Na	(me/100g)	1.92	1.86	2.52
Ca+Mg	(me/100g)	0.03	0.04	0.04
1:5 EXTRACT				
EC_5@ 25°C	(mmhos/cm)	0.8	0.6	0.5
Ca+Mg	(me/1)	0.63	0.42	0.39
EXCHANCEABLE SODIUM	(percent)	72.0	75.0	60.0
ACIDITY				
IN KCL exchange acidity				
Total	(me/100g)			
Al+++	(me/100g)			
CATION EXCHANCE CAPACITY	(me/100g)	12.6	11.9	20.3
NaOAc@pH 8.2				
BORON	(mg/1)			

Table 38
Sheet 3 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis

DH-79-109

Study Area: Rattlesnake Butte Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. _____ Range _____ Elevation: _____ _____ Soil Series: _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Glimate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (mg/l)					
Laboratory Number		14,352	14,353	14,354	14,355	14,443	14,444
Sack Number		79-109-1	79-109-2	79-109-3	79-109-4	79-109-5	79-109-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIG	As						
BORON	B	1.2	5.0	3.5	0.9	2.7	1.7
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Gd	0.14	0.14	0.30	0.18	0.24	0.14
GOBALT	Co						
CHROMIUM	Cr						
GOPPER	Gu	5.0	6.2	16.0	7.6	17.0	9.6
IRON	Fe	112.0	88.0	296.0	102.0	306.0	140.0
MERGURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	26.8	14.0	54.0	8.0	5.0	28.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	8.8	6.8	8.8	5.0	12.0	7.4
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZING	Zn	2.8	5.4	12.0	6.4	15.0	6.4

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,352	14,353	14,354	14,355	14,443	14,444
Sack Number		79-109-1	79-109-2	79-109-3	79-109-4	79-109-5	79-109-6
DEPTH	(Ft)	0.0-16.0	16.9-25.8	29.5-46.5	46.5-57.5	70.0-91.8	94.2-116.1
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
TOTAL SAND	(2.0-0.05 mm)	1.0	39.9	2.5	36.1	0.6	13.7
SILT	(0.05-0.002 mm)	46.0	32.9	55.1	38.6	56.5	64.7
CLAY	(0.002 mm)	53.0	27.2	42.4	25.3	42.9	21.6
TEXTURAL CLASS (LAB)		SiC	GL	SiG	L	SiC	SiL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUGTIVITY	(in/hr)						
6th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	74	157	235	220	120	58
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.7	9.5	9.8	10.0	9.5	10.0
1:2 0.01 M $CaCl_2$							
ORCANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
CYPSUM REQUIREMENT	(me/100g)	-3.0	+9.6	+16.7	+15.9	+14.9	+18.0
SATURATION EXTRACT							
Saturation Percentage		134.4	66.0	111.0	101.1	104.8	68.0
EC_e@ 25°C	(mmhos/cm)	9.8	4.9	2.8	2.5	2.7	2.7
Ca++	(me/l)	20.31	1.04	0.22	0.22	0.38	0.66
Mg++	(me/l)	9.95	0.90	0.09	0.09	0.09	0.27
Na+	(me/l)	93.26	49.98	29.99	25.68	28.93	40.80
K+	(me/l)	0.82	0.41	0.25	0.17	0.26	0.29
CO_3-	(me/l)	0.00	0.00	0.00	0.23	0.00	1.59
HCO_3-	(me/l)	1.92	12.94	17.08	15.92	14.85	21.43
Cl-	(me/l)	0.12	0.22	0.16	0.16	0.23	0.25
SO_4-	(me/l)	122.20	41.70	12.74	9.25	9.89	13.34
NO_3-	(me/l)					0.34	0.68
SAR	(me/l)	17.0	51.0	76.0	65.0	60.0	60.0
Na	(me/100g)	12.53	3.30	3.33	2.60	3.03	2.77
Ca+Mg	(me/100g)	3.95	0.13	0.03	0.03	0.05	0.06
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	4.1	0.9	1.1	1.0		
Ca+Mg	(me/l)	11.90	1.49	1.04	1.08		
EXCHANGEABLE SODIUM	(percent)	30.0	49.0	74.0	74.0	69.0	92.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	15.7	18.8	23.1	19.5	17.1	18.3
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 39
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA

Geologic Core Analysis (cont.)

DH-79-109

Study Area: Rattlesnake Butte Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. _____ Range _____ Elevation: _____ _____ Soil Series: _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Climate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (mg/1)
Laboratory Number		14,445
Sack Number		79-109-7
Depth		
ALUMINUM	Al	
SILVER	Ag	
ARSENIC	As	
BORON	B	2.5
BARIUM	Ba	
BERYLLIUM	Be	
CADMIUM	Cd	0.18
COBALT	Co	
CHROMIUM	Cr	
COPPER	Cu	6.4
IRON	Fe	66.0
MERCURY	Hg	
LITHIUM	Li	
MANGANESE	Mn	8.0
MOLYBDENUM	Mo	
NICKEL	Ni	
PHOSPHOROUS	P	
LEAD	Pb	6.2
STRONTIUM	Sr	
SELENIUM	Se	
VANADIUM	V	
ZINC	Zn	11.0

LABORATORY DESCRIPTION		
DETERMINATION		DATA
Laboratory Number		14,445
Sack Number		79-109-7
DEPTH	(Ft)	119.7-137.5
PARTICLE SIZE ANALYSIS	(percent)	
Very Coarse Sand	(2.0-1.0 mm)	
Coarse Sand	(1.0-0.5 mm)	
Medium Sand	(0.5-0.25 mm)	
Fine Sand	(0.25-0.10 mm)	
Very Fine Sand	(0.10-0.05 mm)	
TOTAL SAND	(2.0-0.05 mm)	51.6
SILT	(0.05-0.002 mm)	36.2
CLAY	(0.002 mm)	12.2
TEXTURAL CLASS (LAB)		L
BULK DENSITY	(g/cm^3)	
HYDRAULIC CONDUCTIVITY	(in/hr)	
6th Hr.		0.00
24th Hr.		0.00
SETTLING VOLUME	(ml)	35
MOISTURE RETENTION	(percent)	
1/10 bar		
1/3 bar		
15 bar		
SOIL REACTION-pH		
Paste		
1:5 H_2O		9.8
1:2 0.01 M $CaCl_2$		
ORGANIC CARBON	(percent)	
AVAILABLE PHOSPHORUS	(ppm)	
$CaCO_3$ EQUIVALENT	(percent)	
GYPSUM REQUIREMENT	(me/100g)	+9.2
SATURATION EXTRACT		
Saturation Percentage		74.9
EC_e @ 25°C	(mmhos/cm)	3.8
Ca^{++}	(me/1)	1.76
Mg^{++}	(me/1)	0.54
Na^{+}	(me/1)	41.90
K^{+}	(me/1)	0.25
CO_3^{-}	(me/1)	0.00
HCO_3^{-}	(me/1)	15.79
Cl^{-}	(me/1)	0.24
SO_4^{-}	(me/1)	21.74
NO_3^{-}	(me/1)	0.60
SAR	(me/1)	39.0
Na	(me/100g)	3.14
Ca+Mg	(me/100g)	0.17
1:5 EXTRACT		
EC_5 @ 25°C	(mmhos/cm)	
Ca+Mg	(me/1)	
EXCHANGEABLE SODIUM	(percent)	60.0
ACIDITY		
IN KCL exchange acidity		
Total	(me/100g)	
Al^{+++}	(me/100g)	
CATION EXCHANGE CAPACITY	(me/100g)	12.2
NaOAc@pH 8.2		
BORON	(mg/1)	

Table 39
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis
DH-79-110

Study Area: Rattlesnake Butte | Relief: | Stoniness: | Parent Material:

Location. Sec. ____ Twp. ____ Range ____ | Elevation: | | Soil Series:

Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: | Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		14,446	14,447	14,448	14,449	14,450	14,451
Sack Number		79-110-1	79-110-2	79-110-3	79-110-4	79-110-5	79-110-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	2.3	2.2	2.0	1.3	2.8	1.6
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.14	0.20	0.20	0.30	0.14	0.20
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	6.6	8.8	11.0	12.0	9.0	15.0
IRON	Fe	82.0	128.0	128.0	138.0	208.0	122.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	30.0	16.0	16.0	18.0	26.0	8.8
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	21.0	6.4	8.0	8.0	6.0	10.0
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	5.8	7.4	8.8	9.8	8.0	7.4

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,446	14,447	14,448	14,449	14,450	14,451
Sack Number		79-110-1	79-110-2	79-110-3	79-110-4	79-110-5	79-110-6
DEPTH	(Ft)	0.0-20.0	20.0-40.0	40.0-64.0	76.2-90.0	90.0-107.5	109.3-125.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
TOTAL SAND	(2.0-0.05 mm)	11.8	18.1	25.3	19.2	12.5	3.2
SILT	(0.05-0.002 mm)	67.2	58.5	46.6	54.3	65.1	66.4
CLAY	(0.002 mm)	21.0	23.4	28.1	26.5	22.4	30.4
TEXTURAL CLASS (LAB)		SiL	SiL	CL	SiL	SiL	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.04	0.00	0.00	0.00	0.00	0.00
24th Hr.		0.06	0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	24	38	54	60	89	70
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.9	9.4	9.7	9.2	9.9	9.6
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-11.3	+8.2	+12.6	+10.1	+13.1	+13.6
SATURATION EXTRACT							
Saturation Percentage		50.5	74.3	85.9	76.3	100.3	89.3
EC_e@ 25°C	(mmhos/cm)	7.1	4.2	3.6	3.4	1.9	2.5
Ca++	(me/l)	26.73	1.26	0.38	0.49	0.22	0.33
Mg++	(me/l)	26.50	1.62	0.45	0.54	0.09	0.27
Na+	(me/l)	43.57	40.70	35.15	35.82	19.32	25.87
K+	(me/l)	1.53	0.73	0.42	0.48	0.23	0.28
CO_3-	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3-	(me/l)	3.01	8.25	10.25	11.94	11.09	12.67
Cl-	(me/l)	0.62	0.27	0.27	0.26	0.25	0.24
SO_4-	(me/l)	95.67	34.56	24.82	21.28	6.70	10.34
NO_3-	(me/l)	0.79	0.27	0.13	0.31	0.13	0.17
SAR	(me/l)	8.4	34.0	55.0	50.0	49.0	47.0
Na	(me/100g)	2.20	3.02	3.02	2.73	1.94	2.31
Ca+Mg	(me/100g)	2.69	0.21	0.07	0.08	0.03	0.05
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)						
Ca+Mg	(me/l)						
EXCHANGEABLE SODIUM	(percent)	6.0	34.0	51.0	46.0	60.0	52.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	12.5	19.6	19.8	17.8	15.3	20.3
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 40
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis (cont.)
DH-79-110

Study Area: Rattlesnake Butte | Relief: | Stoniness: | Parent Material:

Location. Sec. ____ Twp. ____ Range ____ | Elevation: | | Soil Series:

Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: | Date:

DETERMINATION		DATA (mg/1)	
Laboratory Number		14,452	14,453
Sack Number		79-110-7	79-110-8
Depth			
ALUMINUM	Al		
SILVER	Ag		
ARSENIC	As		
BORON	B	2.2	1.6
BARIUM	Ba		
BERYLLIUM	Be		
CADMIUM	Cd	0.14	0.24
COBALT	Co		
CHROMIUM	Cr		
COPPER	Cu	8.8	11.0
IRON	Fe	106.0	86.0
MERCURY	Hg		
LITHIUM	Li		
MANGANESE	Mn	4.8	2.0
MOLYBDENUM	Mo		
NICKEL	Ni		
PHOSPHOROUS	P		
LEAD	Pb	5.2	7.6
STRONTIUM	Sr		
SELENIUM	Se		
VANADIUM	V		
ZINC	Zn	7.0	19.0

LABORATORY DESCRIPTION			
DETERMINATION		DATA	
Laboratory Number		14,452	14,453
Sack Number		79-110-7	79-110-8
DEPTH	(Ft)	125.0-136.2	149.0-164.2
PARTICLE SIZE ANALYSIS	(percent)		
Very Coarse Sand	(2.0-1.0 mm)		
Coarse Sand	(1.0-0.5 mm)		
Medium Sand	(0.5-0.25 mm)		
Fine Sand	(0.25-0.10 mm)		
Very Fine Sand	(0.10-0.05 mm)		
TOTAL SAND	(2.0-0.05 mm)	42.3	25.9
SILT	(0.05-0.002 mm)	36.7	46.7
CLAY	(0.002 mm)	21.0	27.4
TEXTURAL CLASS (LAB)		L	CL
BULK DENSITY	(g/cm^3)		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th Hr.		0.00	0.00
24th Hr.		0.00	0.00
SETTLING VOLUME	(ml)	68	76
MOISTURE RETENTION	(percent)		
1/10 bar			
1/3 bar			
15 bar			
SOIL REACTION-pH			
Paste			
1:5 H_2O		9.8	9.3
1:2 0.01 M $CaCl_2$			
ORGANIC CARBON	(percent)		
AVAILABLE PHOSPHORUS	(ppm)		
Ca CO_3 EQUIVALENT	(percent)		
GYPSUM REQUIREMENT	(me/100g)	+11.6	+10.2
SATURATION EXTRACT			
Saturation Percentage		73.9	76.4
EC_e@ 25° C	(mmhos/cm)	2.4	3.6
Ca++	(me/1)	0.27	0.55
Mg++	(me/1)	0.18	0.45
Na+	(me/1)	24.01	34.77
K+	(me/1)	0.23	0.39
CO_3-	(me/1)	0.07	0.00
HCO_3-	(me/1)	10.55	8.02
Cl-	(me/1)	0.26	0.29
SO_4-	(me/1)	14.82	24.34
NO_3-	(me/1)	0.14	0.14
SAR	(me/1)	51.0	49.0
Na	(me/100g)	1.77	2.66
Ca+Mg	(me/100g)	0.03	0.07
1:5 EXTRACT			
EC_5@ 25° C	(mmhos/cm)		
Ca+Mg	(me/1)		
EXCHANGEABLE SODIUM	(percent)	55.0	43.0
ACIDITY			
IN KCL exchange acidity			
Total	(me/100g)		
Al+++	(me/100g)		
CATION EXCHANGE CAPACITY	(me/100g)	15.4	19.3
NaOAc@pH 8.2			
BORON	(mg/1)		

Table 40
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA

Ceologic Core Analysis

DH-79-111

Study Area: Rattlesnake Butte Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. _____ Range _____ Elevation: _____ _____ Soil Series: _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Climate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (mg/1)					
Laboratory Number		14,454	14,455	14,456	14,457	14,458	14,459
Sack Number		79-111-1	79-111-2	79-111-3	79-111-4	79-111-5	79-111-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	4.5	5.0	0.9	0.6	1.1	1.3
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.12	0.04	0.04	0.02	0.02	0.02
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	7.0	6.6	1.6	1.2	0.8	1.4
IRON	Fe	244.0	60.0	58.0	70.0	70.0	64.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	15.0	6.8	6.0	6.0	6.0	4.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	8.2	6.4	3.8	3.4	1.4	2.4
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	3.2	10.0	1.6	1.6	2.0	4.0

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,454	14,455	14,456	14,457	14,458	14,459
Sack Number		79-111-1	79-111-2	79-111-3	79-111-4	79-111-5	79-111-6
DEPTH	(Ft)	0-20.3	20.3-34.5	34.5-55.0	55.0-75.0	75.0-100.0	100.0-124.5
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)			0.1	0.1	0.0	0.1
Coarse Sand	(1.0-0.5 mm)			0.1	0.2	0.2	0.2
Medium Sand	(0.5-0.25 mm)			3.3	1.4	1.1	0.9
Fine Sand	(0.25-0.10 mm)			61.7	61.6	47.9	48.9
Very Fine Sand	(0.10-0.05 mm)			18.8	22.6	29.8	32.5
TOTAL SAND	(2.0-0.05 mm)	10.9	37.5	84.0	85.9	79.0	82.6
SILT	(0.05-0.002 mm)	49.4	42.9	10.0	9.0	15.5	11.0
CLAY	(0.002 mm)	39.7	19.6	6.0	5.1	5.5	6.4
TEXTURAL CLASS (LAB)		SiCL	L	LFS	LFS	LFS	LFS
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.02	0.00	0.91	1.54	0.20	0.06
24th Hr.		0.02	0.00	0.75	1.42	0.16	0.04
SETTLING VOLUME	(ml)	48	46	20	17	18	20
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.9	9.2	9.1	8.9	9.5	9.8
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-3.0	+7.3	+0.8	-0.4	+0.5	+1.7
SATURATION EXTRACT							
Saturation Percentage		71.6	49.2	30.8	30.2	28.3	29.4
EC_e @ 25°C	(mmhos/cm)		6.9	3.3	1.4	2.8	3.6
Ca++	(me/1)	21.41	1.43	1.98	5.16	1.43	0.60
Mg++	(me/1)	35.30	1.36	1.53	3.07	0.99	0.36
Na+	(me/1)	102.80	65.28	19.32	5.55	24.53	34.91
K+	(me/1)	1.09	0.58	0.62	0.75	0.61	0.40
CO_3-	(me/1)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3-	(me/1)	6.03	10.39	4.04	3.26	4.86	6.91
Cl-	(me/1)	1.54	0.49	1.55	0.90	0.77	1.21
SO_4-	(me/1)	156.50	58.30	17.07	10.63	21.17	26.94
NO_3-	(me/1)	1.81	0.07	0.12	0.11	0.03	0.05
SAR	(me/1)	19.0	55.0	15.0	2.7	22.0	50.0
Na	(me/100g)	7.36	3.32	0.60	0.17	0.69	1.03
Ca+Mg	(me/100g)	3.99	0.14	0.11	0.25	0.07	0.03
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	3.6	0.9	0.2	0.2	0.3	0.4
Ca+Mg	(me/1)	16.68	0.71	0.48	0.86	0.45	0.52
EXCHANGEABLE SODIUM	(percent)	22.0	52.0	11.0	3.1	18.0	42.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	20.4	9.7	4.3	3.0	3.9	3.0
NaOAc@pH 8.2							
BORON	(mg/1)						

Table 41
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis (cont.)
DH-79-111

Study Area: Rattlesnake Butte Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. _____ Range _____ Elevation: _____ _____ Soil Series: _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Climate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (mg/l)		
Laboratory Number		14,460	14,461	14,462
Sack Number		79-111-7	79-111-8	79-111-9
Depth				
ALUMINUM	Al			
SILVER	Ag			
ARSENIC	As			
BORON	B	3.3	2.8	0.7
BARIUM	Ba			
BERYLLIUM	Be			
CADMIUM	Cd	0.24	0.24	0.04
COBALT	Co			
CHROMIUM	Cr			
COPPER	Cu	11.0	17.0	2.0
IRON	Fe	202.0	202.0	160.0
MERCURY	Hg			
LITHIUM	Li			
MANGANESE	Mn	34.0	26.0	21.0
MOLYBDENUM	Mo			
NICKEL	Ni			
PHOSPHOROUS	P			
LEAD	Pb	7.2	11.0	5.8
STRONTIUM	Sr			
SELENIUM	Se			
VANADIUM	V			
ZINC	Zn	12.0	11.0	2.0

LABORATORY DESCRIPTION				
DETERMINATION		DATA		
Laboratory Number		14,460	14,461	14,462
Sack Number		79-111-7	79-111-8	79-111-9
DEPTH	(Ft)	124.5-147.0	147.0-159.0	159.0-184.5
PARTICLE SIZE ANALYSIS	(percent)			
Very Coarse Sand	(2.0-1.0 mm)			
Coarse Sand	(1.0-0.5 mm)			
Medium Sand	(0.5-0.25 mm)			
Fine Sand	(0.25-0.10 mm)			
Very Fine Sand	(0.10-0.05 mm)			
TOTAL SAND	(2.0-0.05 mm)	23.2	4.4	19.1
SILT	(0.05-0.002 mm)	50.9	64.9	37.5
CLAY	(0.002 mm)	25.9	30.7	43.4
TEXTURAL CLASS (LAB)		SiL	SiCL	C
BULK DENSITY	(g/cm^3)			
HYDRAULIC CONDUCTIVITY	(in/hr)			
6th Hr.		0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00
SETTLING VOLUME	(ml)	82	108	122
MOISTURE RETENTION	(percent)			
1/10 bar				
1/3 bar				
15 bar				
SOIL REACTION-pH				
Paste				
1:5 H_2O		9.6	9.8	8.9
1:2 0.01 M $CaCl_2$				
ORGANIC CARBON	(percent)			
AVAILABLE PHOSPHORUS	(ppm)			
Ca CO_3 EQUIVALENT	(percent)			
CYPSUM REQUIREMENT	(me/100g)	+12.2	+12.0	+13.6
SATURATION EXTRACT				
Saturation Percentage		81.4	86.5	92.3
EC_e @ 25°C	(mmhos/cm)	3.2	2.8	4.8
Ca++	(me/1)	0.22	0.38	0.18
Mg++	(me/1)	0.27	0.18	0.54
Na+	(me/1)	33.43	28.70	49.31
K+	(me/1)	0.28	0.29	0.54
CO_3-	(me/1)	0.11	1.02	0.00
HCO_3-	(me/1)	16.68	14.51	20.96
Cl-	(me/1)	0.28	0.19	0.21
SO_4-	(me/1)	14.10	10.95	28.52
NO_3-	(me/1)	0.03	0.06	0.20
SAR	(me/1)	68.0	54.0	65.0
Na	(me/100g)	2.72	2.48	4.55
Ca+Mg	(me/100g)	0.04	0.05	0.11
1:5 EXTRACT				
EC_5 @ 25°C	(mmhos/cm)	0.9	0.8	1.1
Ca+Mg	(me/1)	1.73	2.64	1.41
EXCHANGEABLE SODIUM	(percent)	59.0	54.0	45.0
ACIDITY				
IN KCL exchange acidity				
Total	(me/100g)			
Al+++	(me/100g)			
CATION EXCHANGE CAPACITY	(me/100g)	18.5	18.3	21.7
NaOAc@pH 8.2				
BORON	(mg/l)			

Table 41
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis

DH-79-112

Study Area: Rattlesnake Butte | Relief: | Stoniness: | Parent Material:

Location. Sec. ____ Twp. ____ Range ____ | Elevation: | | Soil Series:

Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: ____ Date: ____

DETERMINATION		DATA (mg/l)					
Laboratory Number		14,463	14,464	14,465	14,466	14,467	14,468
Sack Number		79-112-1	79-112-2	79-112-3	79-112-4	79-112-5	79-112-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.6	3.5	6.8	2.5	3.1	1.4
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.08	0.06	0.10	0.12	0.14	0.14
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	1.6	1.6	8.2	5.6	7.4	8.6
IRON	Fe	160.0	150.0	82.0	286.0	302.0	316.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	8.0	7.8	22.0	22.0	77.8	79.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	2.2	2.4	8.6	6.8	6.2	6.4
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	2.2	2.4	4.4	8.0	7.4	9.6

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,463	14,464	14,465	14,466	14,467	14,468
Sack Number		79-112-1	79-112-2	79-112-3	79-112-4	79-112-5	79-112-6
DEPTH	(Ft)	0.0-17.0	17.0-34.3	38.9-58.0	58.0-68.0	68.0-78.5	78.5-99.2
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.2	0.1				
Coarse Sand	(1.0-0.5 mm)	12.0	9.9				
Medium Sand	(0.5-0.25 mm)	32.9	23.8				
Fine Sand	(0.25-0.10 mm)	20.8	36.9				
Very Fine Sand	(0.10-0.05 mm)	7.2	8.1				
TOTAL SAND	(2.0-0.05 mm)	73.1	78.8	2.8	5.1	0.4	5.0
SILT	(0.05-0.002 mm)	14.5	10.4	75.9	52.9	60.8	55.3
CLAY	(0.002 mm)	12.4	10.8	21.3	42.0	38.8	39.7
TEXTURAL CLASS (LAB)		SL	SL	SiL	SiC	SiCL	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.59	0.94	0.02	0.00	0.00	0.00
24th Hr.		0.55	0.98	0.02	0.00	0.00	0.00
SETTLINC VOLUME	(ml)	21	22	25	68	77	77
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		9.0	8.3	8.7	9.0	9.6	9.6
1:2 0.01 M $CaCl_2$							
ORCANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
CYPSUM REQUIREMENT	(me/100g)	-0.2	+0.1	+1.8	+10.0	+11.9	+11.8
SATURATION EXTRACT							
Saturation Percentage		30.4	33.5	50.2	77.4	101.6	82.6
EC_e@ 25°C	(mmhos/cm)	0.98	0.93	4.4	3.8	2.9	3.3
Ca++	(me/l)	1.54	1.98	6.15	0.82	0.44	0.71
Mg++	(me/l)	2.70	1.35	5.96	0.45	0.18	0.36
Na+	(me/l)	5.60	5.60	35.01	38.12	29.70	33.67
K+	(me/l)	0.20	0.25	1.02	0.50	0.30	0.36
CO_3-	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3-	(me/l)	4.04	1.82	5.43	13.27	12.93	13.69
Cl-	(me/l)	0.99	0.85	0.22	0.23	0.24	0.24
SO_4-	(me/l)	4.16	5.41	39.56	23.38	15.32	16.63
NO_3-	(me/l)	0.51	0.47	0.28	0.23	0.09	0.06
SAR	(me/l)	3.8	4.3	14.0	48.0	53.0	46.0
Na	(me/100g)	0.17	0.19	1.76	2.97	3.02	2.78
Ca+Mg	(me/100g)	0.13	0.12	0.61	0.10	0.06	0.09
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.2	0.1	0.7	0.9	0.9	0.9
Ca+Mg	(me/l)	1.22	1.17	1.01	1.38	1.62	1.48
EXCHANGEABLE SODIUM	(percent)	3.7	3.9	12.0	39.0	56.0	51.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANCE CAPACITY	(me/100g)	7.0	8.5	13.0	21.7	16.3	16.9
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 42
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis (cont.)
DH-79-112

Study Area: Rattlesnake Butte Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. _____ Range _____ Elevation: _____ _____ Soil Series: _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Climate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (mg/l)				
Laboratory Number		14,469	14,470	14,471	14,472	14,473
Sack Number		79-112-7	79-112-8	79-112-9	79-112-10	79-112-11
Depth						
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	2.2	2.5	1.9	1.5	2.6
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.04	0.14	0.30	0.16	0.06
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	2.2	10.0	16.0	9.0	3.0
IRON	Fe	102.0	258.0	116.0	102.0	170.0
MERCURY	Hg					
LITHIUM	Li					
MANGANESE	Mn	10.0	54.0	10.0	12.0	10.0
MOLYBDENUM	Mo					
NICKEL	Ni					
PHOSPHORUS	P					
LEAD	Pb	3.6	5.6	11.0	6.2	2.6
STRONTIUM	Sr					
SELENIUM	Se					
VANADIUM	V					
ZINC	Zn	8.2	8.8	15.0	6.2	10.0

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		14,469	14,470	14,471	14,472	14,473
Sack Number		79-112-7	79-112-8	79-112-9	79-112-10	79-112-11
DEPTH	(Ft)	99.2-119.5	119.5-138.5	145.0-165.0	165.0-181.8	182.0-204.5
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)	0.1				0.1
Coarse Sand	(1.0-0.5 mm)	0.2				0.9
Medium Sand	(0.5-0.25 mm)	3.2				20.3
Fine Sand	(0.25-0.10 mm)	62.3				51.1
Very Fine Sand	(0.10-0.05 mm)	16.3				8.9
TOTAL SAND	(2.0-0.05 mm)	82.1	6.2	6.6	29.1	81.3
SILT	(0.05-0.002 mm)	11.8	67.5	64.2	52.0	8.9
CLAY	(0.002 mm)	6.1	26.3	29.2	18.9	9.8
TEXTURAL CLASS (LAB)		LFS	SiL	SiCL	SiL	LFS
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.10	0.00	0.00	0.00	0.00
24th Hr.		0.10	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	20	62	70	75	70
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar						
SOIL REACTION-pH						
Paste						
1:5 H_2O		9.6	9.8	9.8	9.9	10.0
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
Ca CO_3 EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	+7.5	+14.4	+20.0	+20.0	+12.2
SATURATION EXTRACT						
Saturation Percentage		28.8	79.9	95.2	82.1	54.8
EC_e@ 25° C	(mmhos/cm)	3.3	2.8	2.7	3.6	3.9
Ca++	(me/l)	2.20	0.33	0.44	0.22	0.22
Mg++	(me/l)	0.81	0.18	0.18	0.09	0.09
Na+	(me/l)	30.66	29.51	28.50	38.20	39.40
K+	(me/l)	0.51	0.32	0.23	0.36	0.23
CO_3-	(me/l)	0.00	0.00	0.00	1.04	0.60
HCO_3-	(me/l)	5.21	16.40	13.85	19.99	9.84
Cl-	(me/l)	0.57	0.21	0.24	0.22	0.25
SO_4-	(me/l)	25.61	12.03	12.51	16.34	28.63
NO_3-	(me/l)	0.41	0.03	0.27	0.16	0.08
SAR	(me/l)	25.0	58.0	51.0	97.0	100.0
Na	(me/100g)	0.88	2.36	2.71	3.13	2.16
Ca+Mg	(me/100g)	0.08	0.04	0.06	0.03	0.06
1:5 EXTRACT						
EC_5@ 25° C	(mmhos/cm)	0.1	0.8	0.9	1.1	0.7
Ca+Mg	(me/l)	0.16	1.18	1.51	1.81	2.46
EXCHANGEABLE SODIUM	(percent)	36.0	54.0	69.0	67.0	61.0
ACIDITY						
IN KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	2.4	12.9	17.0	17.4	8.1
NaOAc@pH 8.2						
BORON	(mg/l)					

Table 42
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis
DH-79-113

Study Area: Rattlesnake Butte
Location. Sec.____ Twp._____ Range_____
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Ground Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By:
Date:

DETERMINATION		DATA (mg/1)				
Laboratory Number		14,474	14,475	14,476	14,477	14,478
Sack Number		79-113-1	79-113-2	79-113-3	79-113-4	79-113-5
Depth						
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	2.6	3.8	3.3	3.1	2.8
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.18	0.20	0.24	0.14	0.24
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	9.6	14.0	17.0	9.2	15.0
IRON	Fe	170.0	200.0	344.0	92.0	246.0
MERCURY	Hg					
LITHIUM	Li					
MANCANESE	Mn	32.0	26.0	60.0	8.0	50.0
MOLYBDENUM	Mo					
NICKEL	Ni					
PHOSPHOROUS	P					
LEAD	Pb	5.2	7.8	8.4	9.4	7.0
STRONTIUM	Sr					
SELENIUM	Se					
VANADIUM	V					
ZINC	Zn	5.6	13.0	15.0	9.0	11.0

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		14,474	14,475	14,476	14,477	14,478
Sack Number		79-113-1	79-113-2	79-113-3	79-113-4	79-113-4
DEPTH	(Ft)	0-28.5	28.5-53.0	63.0-86.8	87.6-98.8	102.6-113.1
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
TOTAL SAND	(2.0-0.05 mm)	25.0	17.9	1.3	51.5	16.7
SILT	(0.05-0.002 mm)	44.6	48.5	61.6	24.5	59.1
CLAY	(0.002 mm)	30.4	33.6	37.1	24.0	24.2
TEXTURAL CLASS (LAB)		CL	SiCL	SiCL	SCL	SiL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.00	0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	125.0	177.0	145.0	156.0	123.0
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar						
SOIL REACTION-pH						
Paste						
1:5 H_2O		9.0	9.8	9.8	9.9	9.9
1:2 0.01 M $CaCl_2$						
ORCANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
Ca CO_3 EQUIVALENT	(percent)					
CYPSUM REQUIREMENT	(me/100g)	+9.5	+17.3	+14.7	+13.5	+18.4
SATURATION EXTRACT						
Saturation Percentage		106.5	122.3	103.9	121.5	108.9
EC_e@ 25°C	(mmhos/cm)	7.1	3.6	3.1	2.2	2.5
Ca++	(me/1)	7.63	0.33	0.33	0.11	0.16
Mg++	(me/1)	9.41	0.18	0.18	0.09	0.09
Na+	(me/1)	70.30	34.00	32.80	22.70	26.10
K+	(me/1)	0.84	0.31	0.33	0.15	0.22
CO_3-	(me/1)	0.00	0.00	0.00	0.00	0.95
HCO_3-	(me/1)	4.68	13.87	18.76	12.21	17.28
Cl-	(me/1)	0.56	0.23	0.22	0.23	0.24
SO_4-	(me/1)	81.72	19.45	14.01	9.78	6.06
NO_3-	(me/1)	0.88	<0.03	<0.03	<0.03	<0.03
SAR	(me/1)	24.0	67.0	65.0	72.0	74.0
Na	(me/100g)	7.54	4.16	3.41	2.76	2.84
Ca+Mg	(me/100g)	1.81	0.06	0.05	0.02	0.03
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	1.7	1.1	0.9	0.9	0.8
Ca+Mg	(me/1)	0.86	3.18	2.65	3.13	2.52
EXCHANGEABLE SODIUM	(percent)	22.0	57.0	58.0	70.0	66.0
ACIDITY						
IN KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANCE CAPACITY	(me/100g)	21.0	23.0	18.3	18.5	20.0
NaOAc@pH 8.2						
BORON	(mg/1)					

Table 43
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis (cont.)
DH-79-113

Study Area: Rattlesnake Butte Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. ____ Range ____ Elevation: _____ _____ Soil Series: _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Climate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (mg/l)				
Laboratory Number		14,479	14,480	14,481	14,482	14,483
Sack Number		79-113-6	79-113-7	79-113-8	79-113-9	79-113-10
Depth						
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	1.7	1.9	1.6	2.2	1.3
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.14	0.12	0.08	0.06	0.06
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	18.0	8.0	3.8	2.6	2.0
IRON	Fe	122.0	70.0	272.0	144.0	132.0
MERCURY	Hg					
LITHIUM	Li					
MANGANESE	Mn	18.0	10.0	38.0	14.0	12.0
MOLYBDENUM	Mo					
NICKEL	Ni					
PHOSPHOROUS	P					
LEAD	Pb	10.0	6.8	3.4	2.6	3.0
STRONTIUM	Sr					
SELENIUM	Se					
VANADIUM	V					
ZINC	Zn	6.8	5.6	4.6	4.4	4.2

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		14,479	14,480	14,481	14,482	14,483
Sack Number		79-113-6	79-113-7	79-113-8	79-113-9	79-113-10
DEPTH	(Ft)	113.1-127.6	129.0-143.0	143.0-160.0	160.0-174.5	174.5-200.5
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)		0.2	0.0	0.1	0.1
Coarse Sand	(1.0-0.5 mm)		0.6	3.1	0.4	2.6
Medium Sand	(0.5-0.25 mm)		1.2	20.7	3.5	16.8
Fine Sand	(0.25-0.10 mm)		21.3	34.4	58.7	53.2
Very Fine Sand	(0.10-0.05 mm)		37.5	22.2	19.8	9.7
TOTAL SAND	(2.0-0.05 mm)	31.2	60.8	80.4	82.5	82.4
SILT	(0.05-0.002 mm)	41.8	23.0	9.4	8.3	8.0
CLAY	(0.002 mm)	27.0	16.2	10.2	9.2	9.6
TEXTURAL CLASS (LAB)		CL	VFSL	LFS	LFS	LFS
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.00	0.00	0.00	0.04	0.00
24th Hr.		0.00	0.00	0.00	0.02	0.00
SETTLING VOLUME	(ml)	103	80	34	30	32
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar						
SOIL REACTION-pH						
Paste						
1:5 H_2O		10.0	10.0	9.9	10.0	10.1
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
Ca CO_3 EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	+12.0	+7.2	+6.2	+6.6	
SATURATION EXTRACT						
Saturation Percentage		101.1	63.7	34.2	37.9	34.2
EC_e@ 25°C	(mmhos/cm)	2.7	3.2	4.8	4.3	3.9
Ca++	(me/1)	0.22	0.55	0.49	0.49	0.33
Mg++	(me/1)	0.09	0.18	0.18	0.18	0.09
Na+	(me/1)	27.70	33.70	51.40	45.10	41.10
K+	(me/1)	0.18	0.26	0.21	0.17	0.15
CO_3-	(me/1)	0.38	0.00	1.58	0.14	0.73
HCO_3-	(me/1)	13.71	15.19	19.15	15.30	16.28
Cl-	(me/1)	0.21	0.25	0.32	0.26	0.28
SO_4-	(me/1)	10.41	16.18	29.56	27.30	22.07
NO_3-	(me/1)	<0.03	<0.03	0.10	0.04	0.48
SAR	(me/1)	70.0	56.0	89.0	78.0	90.0
Na	(me/100g)	2.80	2.15	1.76	1.71	1.40
Ca+Mg	(me/100g)	0.03	0.05	0.03	0.03	0.01
1:5 EXTRACT						
EC_5@ 25°C	(mmhos/cm)	1.0	0.7	0.6	0.7	0.6
Ca+Mg	(me/1)	1.82	1.64	0.96	0.89	1.13
EXCHANGEABLE SODIUM	(percent)	75.0	62.0	78.0	66.0	67.0
ACIDITY						
IN KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	18.5	13.4	8.6	7.6	7.1
NaOAc@pH 8.2						
BORON	(mg/l)					

Table 43
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Ceologic Core Analysis
DH-79-114

Study Area: Rattlesnake Butte Relief: _____ Stoniness: _____ Parent Material: _____

Location. Sec. ____ Twp. _____ Range _____ Elevation: _____ _____ Soil Series: _____

_____ Slope Aspect: _____ Drainage: _____ Soil Classification: _____

Climate: _____ Vegetation: _____ Ground Water: _____ _____

Land Use: _____ Erosion: _____ Land Form: _____ Profile Description By: _____ Date: _____

DETERMINATION		DATA (mg/1)					
Laboratory Number		14,484	14,485	14,486	14,487	14,488	14,489
Sack Number		79-114-1	79-114-2	79-114-3	79-114-4	79-114-5	79-114-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.3	1.3	1.5	1.6	1.5	2.5
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.02	0.16	0.16	0.12	0.08	0.14
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	1.4	10.0	11.0	4.6	2.4	12.0
IRON	Fe	114.0	326.0	226.0	64.0	112.0	154.0
MERCURY	Hg						
LITHIUM	Li						
MANCANESE	Mn	26.0	32.0	50.0	5.4	10.0	26.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	4.4	5.0	8.0	4.0	4.6	6.0
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	2.2	10.0	10.0	4.2	3.2	5.2

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,484	14,485	14,486	14,487	14,488	14,489
Sack Number		79-114-1	79-114-2	79-114-3	79-114-4	79-114-5	79-114-6
DEPTH	(Ft)	0.0-10.8	11.5-25.0	25.0-40.7	45.4-60.0	60.0-76.0	76.0-90.5
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.4					
Coarse Sand	(1.0-0.5 mm)	6.9					
Medium Sand	(0.5-0.25 mm)	24.0					
Fine Sand	(0.25-0.10 mm)	29.7					
Very Fine Sand	(0.10-0.05 mm)	8.1					
TOTAL SAND	(2.0-0.05 mm)	69.1	3.7	1.5		69.3	
SILT	(0.05-0.002 mm)	17.0	83.9	68.6		10.0	
CLAY	(0.002 mm)	13.9	12.4	29.9		20.7	
TEXTURAL CLASS (LAB)		SL	SiL	SiCL		SCL	
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.55	0.04	0.06	0.00	0.00	0.00
24th Hr.		0.47	0.04	0.08	0.00	0.00	0.00
SETTLINC VOLUME	(ml)	22	29	32	34	34	44
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.4	7.5	8.4	9.1	9.6	9.6
1:2 0.01 M $CaCl_2$							
ORCANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
CYPSUM REQUIREMENT	(me/100g)	0.0	+1.7	+2.6	+8.7	+12.2	+14.0
SATURATION EXTRACT							
Saturation Percentage		33.7	63.5	67.1	57.3	48.6	79.5
EC_e@ 25°C	(mmhos/cm)	1.1	4.1	3.1	2.8	2.4	2.6
Ca++	(me/1)	4.67	15.04	1.15	5.60	0.38	0.38
Mg++	(me/1)	1.18	10.49	0.45	3.44	0.18	0.18
Na+	(me/1)	6.12	23.00	26.50	23.10	23.60	26.30
K+	(me/1)	0.19	1.69	0.56	1.61	0.28	0.35
CO_3-	(me/1)	0.00	0.00	0.00	0.00	0.00	0.15
HCO_3-	(me/1)	6.31	6.87	7.15	7.46	11.60	14.66
Cl-	(me/1)	0.55	0.78	0.28	0.28	0.25	0.21
SO_4-	(me/1)	3.37	39.77	19.47	23.36	11.90	11.85
NO_3-	(me/1)	0.04	0.02	<0.03	<0.02	<0.03	<0.03
SAR	(me/1)	3.6	6.4	30.0	11.0	32.0	50.0
Na	(me/100g)	0.21	1.46	1.78	1.32	1.15	2.09
Ca+Mg	(me/100g)	0.20	1.62	0.11	0.52	0.03	0.04
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.2	0.7	0.6	0.4	0.4	0.7
Ca+Mg	(me/1)	1.19	2.33	0.90	1.12	1.03	1.88
EXCHANCEABLE SODIUM	(percent)	3.8	3.6	3.4	31.0	42.0	42.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANCE CAPACITY	(me/100g)	10.7	17.5	16.9	19.3	19.1	23.8
NaOAc@pH 8.2							
BORON	(mg/1)						

Table 44
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA

Geologic Core Analysis (cont.)

DH-79-114

Study Area: Rattlesnake Butte Relief: Stoniness: Parent Material:

Location. Sec. ____ Twp. ____ Range ____ Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Ground Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (mg/l)	
Laboratory Number		14,490	14,491
Sack Number		79-114-7	79-114-8
Depth			
ALUMINUM	Al		
SILVER	Ag		
ARSENIC	As		
BORON	B	2.0	1.3
BARIUM	Ba		
BERYLLIUM	Be		
CADMIUM	Cd	0.22	0.10
COBALT	Co		
CHROMIUM	Cr		
COPPER	Cu	11.0	5.2
IRON	Fe	216.0	72.0
MERCURY	Hg		
LITHIUM	Li		
MANGANESE	Mn	24.0	6.0
MOLYBDENUM	Mo		
NICKEL	Ni		
PHOSPHOROUS	P		
LEAD	Pb	7.6	4.8
STRONTIUM	Sr		
SELENIUM	Se		
VANADIUM	V		
ZINC	Zn	9.0	5.4

LABORATORY DESCRIPTION			
DETERMINATION		DATA	
Laboratory Number		14,490	14,491
Sack Number		79-114-7	79-114-8
DEPTH	(Ft)	101.0-121.4	123.5-134.5
PARTICLE SIZE ANALYSIS	(percent)		
Very Coarse Sand	(2.0-1.0 mm)		
Coarse Sand	(1.0-0.5 mm)		
Medium Sand	(0.5-0.25 mm)		
Fine Sand	(0.25-0.10 mm)		
Very Fine Sand	(0.10-0.05 mm)		
TOTAL SAND	(2.0-0.05 mm)	19.5	41.1
SILT	(0.05-0.002 mm)	53.7	38.2
CLAY	(0.002 mm)	26.8	20.7
TEXTURAL CLASS (LAB)		SiL	L
BULK DENSITY	(g/cm^3)		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th Hr.		0.00	0.00
24th Hr.		0.00	0.00
SETTLINC VOLUME	(ml)	108	132
MOISTURE RETENTION	(percent)		
1/10 bar			
1/3 bar			
15 bar			
SOIL REACTION-pH			
Paste			
1:5 H_2O		9.8	9.9
1:2 0.01 M $CaCl_2$			
ORCANIC CARBON	(percent)		
AVAILABLE PHOSPHORUS	(ppm)		
Ca CO_3 EQUIVALENT	(percent)		
CYPSUM REQUIREMENT	(me/100g)	+14.8	+16.1
SATURATION EXTRACT			
Saturation Percentage		104.9	93.5
EC_e@ 25 C	(mmhos/cm)	2.0	1.7
Ca++	(me/l)	0.27	0.16
Mg++	(me/l)	0.09	0.09
Na+	(me/l)	20.70	17.10
K+	(me/l)	0.21	0.14
CO_3-	(me/l)	0.20	0.05
HCO_3-	(me/l)	13.45	11.18
Cl-	(me/l)	0.11	0.21
SO_4-	(me/l)	4.58	4.78
NO_3-	(me/l)	0.14	0.14
SAR	(me/l)	49.0	48.0
Na	(me/100g)	2.17	1.60
Ca+Mg	(me/100g)	0.04	0.02
1:5 EXTRACT			
EC_5 @ 25°C	(mmhos/cm)	0.8	0.6
Ca+Mg	(me/l)	2.26	2.63
EXCHANCEABLE SODIUM	(percent)	51.0	70.0
ACIDITY			
IN KCL exchange acidity			
Total	(me/100g)		
Al+++	(me/100g)		
CATION EXCHANCE CAPACITY	(me/100g)	20.5	16.5
NaOAc@pH 8.2			
BORON	(mg/l)		

Table 44
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Water and Power Resources Service
BISMARCK, NORTH DAKOTA
Geologic Core Analysis

DH-79-115

Study Area: Rattlesnake Butte Relief: Stoniness: Parent Material:

Location. Sec. Twp. Range Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Ground Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		14,492	14,493	14,494	14,495	14,496	14,497
Sack Number		79-115-1	79-115-2	79-115-3	79-115-4	79-115-5	79-115-6
Depth							
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	1.3	0.5	1.6	1.9	1.4	2.0
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.10	0.06	0.14	0.08	0.06	0.14
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	4.0	0.8	8.4	4.8	1.8	4.2
IRON	Fe	80.0	98.0	176.0	68.0	190.0	160.0
MERCURY	Hg						
LITHIUM	Li						
MANGANESE	Mn	8.2	24.0	30.0	3.8	7.2	14.0
MOLYBDENUM	Mo						
NICKEL	Ni						
PHOSPHOROUS	P						
LEAD	Pb	15.0	1.8	5.6	5.2	3.2	3.6
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	3.6	3.0	6.0	3.2	6.8	5.4

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		14,492	14,493	14,494	14,495	14,496	14,497
Sack Number		79-115-1	79-115-2	79-115-3	79-115-4	79-115-5	79-115-6
DEPTH	(Ft)	0.0-20.0	20.0-44.4	44.8-55.5	58.2-80.0	80.0-100.0	100.0-124.5
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.2	0.3		0.2	0.4	0.2
Coarse Sand	(1.0-0.5 mm)	0.5	2.3		0.6	1.5	0.5
Medium Sand	(0.5-0.25 mm)	3.0	27.3		11.8	11.9	1.9
Fine Sand	(0.25-0.10 mm)	37.3	47.3		38.9	61.6	19.1
Very Fine Sand	(0.10-0.05 mm)	18.3	4.5		12.2	7.1	35.2
TOTAL SAND	(2.0-0.05 mm)	59.3	81.4	29.4	63.7	82.5	56.9
SILT	(0.05-0.002 mm)	23.9	9.4	55.3	22.8	8.6	29.7
CLAY	(0.002 mm)	16.8	9.2	15.3	13.5	8.9	13.4
TEXTURAL CLASS (LAB)		FSL	LS	SiL	FSL	LFS	VFSL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.04	1.38	0.98	0.00	0.00	0.00
24th Hr.		0.04	1.30	0.98	0.00	0.00	0.00
SETTLING VOLUME	(ml)	30	22	26	37	38	33
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste							
1:5 H_2O		9.4	9.4	9.1	10.0	10.1	10.0
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+2.0	+1.3	+5.3	+9.8	+7.2	+11.2
SATURATION EXTRACT							
Saturation Percentage		40.4	32.7	61.2	43.6	33.7	50.1
EC_e@ 25°C	(mmhos/cm)	1.6	1.1	2.9	2.9	3.9	5.0
Ca++	(me/1)	1.54	0.88	1.59	0.66	0.27	0.49
Mg++	(me/1)	2.08	0.90	1.27	0.27	0.09	0.36
Na+	(me/1)	13.50	8.42	24.50	31.40	41.60	52.80
K+	(me/1)	0.37	0.28	0.65	0.25	0.28	0.53
CO_3-	(me/1)	0.00	0.00	0.00	0.00	2.25	0.65
HCO_3-	(me/1)	8.06	4.44	9.98	10.00	17.06	24.59
Cl-	(me/1)	0.46	0.78	0.23	0.23	0.32	0.24
SO_4-	(me/1)	7.16	4.17	14.57	18.74	21.22	25.92
NO_3-	(me/1)	<0.03	0.28	<0.03	0.13	0.97	0.09
SAR	(me/1)	10.0	8.9	20.0	77.0	98.0	81.0
Na	(me/100g)	0.55	0.27	1.50	1.37	1.40	2.64
Ca+Mg	(me/100g)	0.14	0.06	0.18	0.04	0.04	0.04
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.3	0.2	0.5	0.5	0.7	0.9
Ca+Mg	(me/1)	1.48	1.02	0.75	1.16	1.04	0.85
EXCHANGEABLE SODIUM	(percent)	9.3	21.0	17.0	62.0	50.0	78.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	12.8	8.4	19.0	10.4	7.4	11.9
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 45

Criteria Used to Determine Suitability of Bedrock Material
For Use as Plant Media in Revegetation 1/

Parameter	Methodology	Suitable	Limited Suitability	Unsuitable
Texture	Pipette method plus sand sieving	FSL, VFSL, L, Sil, SCL	LFS, SL, CL, SiCL, SC	S, LS, SiC, C
Electrical Conductivity (mmhos/cm)	Saturation extract/ conductivity bridge	<4	4-12	>12
pH	Saturated paste/ glass electrode	6.0-8.4	5.0-6.0; 8.4-9.0	<5.0; >9.0
Sodium Adsorption Ratio (SAR)	Calculate: $Na/\sqrt{(Ca+Mg)/2}$; Ca,Mg, and Na in meq/l	<6	6-9 heavy textures 6-12 medium and coarse textures	> 9 - heavy textures > 12 - medium and coarse textures
Exchangeable Sodium Percentage (ESP)	Ammonium acetate extraction; calculate: Na/CEC x 100%	<5	5-15	>15 2/
Boron (mg/l)	Hot water extraction/ carmine method	<5		>5
Selenium (mg/l)	Hydride generation; flameless AA	<2		>2
Molybdenum (mg/l)	Ammonium oxalate extraction; flameless AA or N_2O flame AA-5000	<1		>1
Copper (mg/l)	DTPA extraction; AA	3/		3/
Manganese (mg/l)	DTPA extraction; AA	<60		>60
Zinc (mg/l)	DTPA extraction; AA	<40		>40
Lead (mg/l)	DTPA extraction; AA	10-15 (pH <6) 15-20 (pH >6)		> 15 (pH < 6) > 20 (pH > 6)
Cadmium (mg/l)	DTPA extraction; AA	<1		>1
Nickel (mg/l)	DTPA extraction; AA	2-3		>3
Mercury (mg/l)	Extraction by H_2SO_4; flameless AA (quartz cell)	<0.5		>0.5
Iron (mg/l)	-		Not Established	
Nitrate-Nitrogen (mg/l)	-		Not Established	

1/ Applicable only to reclamation study areas in Montana and North Dakota.
2/ Rate 2:1 - Clay texture poor if >10, sand texture if >20.
3/ Suspect level not established - an excessive consumption of molybdenum through injestation of vegetation may be toxic to animals. This concern is directly related to the Cu:Mo ratio in the plant tissue.

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 78-101

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-20.0	Css,Sh	Unsuitable	% clay, saline, cadmium
20.0-40.0	Sh	Unsuitable	% clay, sodic
40.0-67.0	SiSs, Sh	Unsuitable	Sodic, pH
67.0-80.0	SiSs	Unsuitable	Sodic, pH
80.0-103.4	Sh	Unsuitable	Sodic, pH
103.4-122.9	Ss	Unsuitable	Sodic, pH
122.9-132.6	Sh	Unsuitable	% clay, sodic, pH
149.9-165.3	Sh	Unsuitable	Sodic, pH
165.3-185.0	Ss	Unsuitable	Sodic, pH
185.0-205.2	Ss	Unsuitable	Sodic, pH

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 78-102

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-25	Sh	Limited	Saline, sodic
25.0-48.7	Sh	Unsuitable	Sodic
60.8-83.0	Sh, S Sist	Unsuitable	Sodic, pH
83.0-98.0	Sh, S Sist	Unsuitable	Sodic, pH
98.0-112.8	S Sist	Unsuitable	Sodic, pH
112.8-129.5	Ss	Unsuitable	Sodic, pH
129.5-159.9	Sh, Ssh	Unsuitable	Sodic, pH
164.3-174.9	SiSs	Unsuitable	Sodic, pH
174.9-195.0	Sh	Unsuitable	Sodic, pH
195.0-217.7	Sh	Unsuitable	% clay, sodic, pH
217.7-245.6	Ss	Unsuitable	Sodic, pH

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 79-103

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-17.0	Ss, Css, Sh	Limited	Saline, sodic
18.5-40.0	Sh	Unsuitable	Sodic
40.0-55.0	Ssh	Unsuitable	Sodic, pH
57.5-79.0	Css, Sh, Cbsh	Unsuitable	% clay, sodic, pH
90.0-105.0	Cbsh, Ssh	Unsuitable	Sodic, pH
105.0-133.7	Ss	Limited	% Sand, sodic
134.2-140.2	Cbsh, Sh	Unsuitable	Sodic
140.2-154.0	Sh	Unsuitable	Sodic, pH
154.0-174.7	Css, Sh	Unsuitable	Sodic, pH
176.7-194.5	Sh, Ss	Unsuitable	Sodic, pH

Suitability of Bedrock Material for Use as Plant Media in Revegetation-
Rattlesnake Butte Study Area
Bedrock Core DH - 79-104

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-33.5	Ss	Unsuitable	1/
33.5-42.2	Cbsh, Sish	Suitable	-
43.0-54.5	Sh	Suitable	-
54,5-66.0	Ssh, Ss	Unsuitable	Sodic
68.5-84.0	Ss, Sh	Unsuitable	Sodic
85.3-94.5	Sh	Unsuitable	Sodic
103.0-111.1	Sh	Unsuitable	Sodic
113.3-120.0	Sh	Unsuitable	Sodic

1/ Unsuitable designation was applied due to a very high level of lead and a high level of zinc after two lab runs. Both levels correlated poorly with the levels found in similar strata; therefore, they are questionable. All other physical and chemical properties of this material were favorable.

Suitability of Bedrock Material for Use as Plant Media in Revegetation-
Rattlesnake Butte Study Area
Bedrock Core DH - 79-105

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-20.5	Sish	Unsuitable	Sodic
20.5-29.5	Ssh, Sh	Unsuitable	Sodic
30.7-37.9	Sh	Unsuitable	Sodic
49.2-57.1	Css	Unsuitable	Sodic
58.1-65.1	Ssh	Unsuitable	Sodic, pH
67.8-77.0	Ssh	Unsuitable	Sodic, pH
77.0-95.0	Ss	Unsuitable	Sodic, pH
95.0-115.0	Ss	Unsuitable	Sodic, pH
115.0-135.0	Ss	Unsuitable	Sodic, pH
135.0-144.6	Ss	Unsuitable	Sodic, pH
144.9-159.4	Sh, Ss	Unsuitable	Sodic, pH
159.4-172.0	Sh	Unsuitable	Sodic, pH
172.4-180.5	Sh, Ss	Unsuitable	Sodic, pH
180.5-192.5	Sh, Ssh	Unsuitable	Sodic, pH
192.5-233.0	Sh	Unsuitable	% clay, sodic, pH
321.3-244.5	Ssh	Unsuitable	Sodic, pH

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 79-106

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-22.0	Sish	Limited	% clay, saline, sodic
23.5-44.5	Sish	Unsuitable	Sodic
44.5-63.0	Sh	Unsuitable	% clay, sodic
63.0-80.0	Ssh	Unsuitable	Sodic, pH
80.0-96.5	Ssh	Unsuitable	Sodic, pH
108.2-118.0	Sh	Unsuitable	% clay, sodic, pH
118.0-129.5	Css, Sh	Unsuitable	Sodic, pH
129.7-146.7	S Sist	Unsuitable	Sodic, pH
149.7-169.0	Ss	Unsuitable	Sodic, pH
169.0-198.7	Ss	Unsuitable	Sodic, pH
208.2-224.5	Ssh	Unsuitable	Sodic, pH

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 79-107

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-19.2	Ss	Unsuitable	2/
19.7-40.0	Ssh	Unsuitable	% clay
40.0-52.8	Ssh	Limited	Saline
52.8-65.8	Css	Unsuitable	Sodic
65.8-80.0	Ssh	Unsuitable	Sodic, pH
80.0-96.2	Ssh	Unsuitable	Sodic, pH
97.8-120.0	Sh	Unsuitable	Sodic, pH
120.0-138.7	Sh	Unsuitable	Sodic, pH
149.3-166.5	Sh	Unsuitable	Sodic, pH
166.5-181.1	Css, Sh	Unsuitable	Sodic, pH
183.5-187.2	Cbsh	Unsuitable	Sodic
194.7-213.5	Cbsh, Ss	Unsuitable	Sodic, pH

2/ Unsuitable designation was applied due to a very high level of lead (after two lab runs). This level correlated very poorly with lead levels of similar strata; therefore, it is questionable. All other physical and chemical properties of this material were favorable.

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 79-108

Depth(ft)	Type	Suitability	Limiting Factor(s)
0.0-20.0	Sh	Unsuitable	Sodic, lead (Pb)
21.0-36.3	Css, Sh	Unsuitable	% clay, sodic
37.0-47.7	Sh, Css	Unsuitable	Sodic, pH
48.9-63.7	Ssh	Unsuitable	Sodic, pH
63.7-84.0	Ss	Unsuitable	% Sand, sodic, pH
84.0-103.8	Ss	Unsuitable	% Sand, sodic, pH
114.7-130.0	Sish	Unsuitable	Sodic, pH
130.0-142.0	Sish	Unsuitable	Sodic, pH
142.0-147.8	Sh	Unsuitable	% clay, sodic, pH
148.5-158.9	Sh, Cbsh	Unsuitable	Sodic, pH
158.9-170.0	Sish	Unsuitable	Sodic, pH
170.0-192.0	C-Cb Ss	Unsuitable	Sodic
194.9-201.3	Css	Unsuitable	Sodic, pH
202.5-213.3	Sh, Css	Unsuitable	Sodic, pH
220.5-234.5	Css, Cbsh	Unsuitable	Sodic, pH

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 79-109

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-16.0	Sh	Unsuitable	% clay, sodic
16.9-25.8	Cbsh, Css, Sh	Unsuitable	Sodic, pH
29.5-46.5	Sh	Unsuitable	% clay, sodic, pH
46.5-57.5	Ssh, Ss, Sh	Unsuitable	Sodic, pH
70.0-91.8	Sh	Unsuitable	% clay, sodic, pH
94.2-116.1	Css, Sh	Unsuitable	Sodic, pH
119.7-137.5	Ssh, Css	Unsuitable	Sodic, pH

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 79-110

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-20.0	Sh, SiSs, Ssh	Limited	Saline, sodic
20.0-40.0	Ssh	Unsuitable	Sodic
40.0-64.8	Ssh	Unsuitable	Sodic, pH
76.2-90.0	Ssh	Unsuitable	Sodic
90.0-107.5	Ssh	Unsuitable	Sodic
109.3-125.0	Sh	Unsuitable	Sodic
125.0-136.2	Sh, Css	Unsuitable	Sodic, pH
149.0-164.5	Ssh	Unsuitable	Sodic

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 79-111

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-20.3	Sh	Unsuitable	Sodic
28.7-34.5	Css, Ssh	Unsuitable	Sodic
34.5-55.0	Ss	Limited	Sodic
55.0-75.0	Ss	Suitable	-
75.0-100.0	Ss	Unsuitable	Sodic
100.0-124.5	Ss	Unsuitable	Sodic, pH
124.5-147.0	Cbsh, Ssh	Unsuitable	Sodic, pH
149.4-159.0	Sh	Unsuitable	Sodic, pH
175.0-184.5	Cbsh, Css	Unsuitable	% clay, sodic

Suitability of Bedrock Material for Use as Plant Media in Revegetation -

Rattlesnake Butte Study Area
Bedrock Core DH - 79-112

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-17.0	Ss	Suitable	-
17.0-34.3	Ss	Suitable	-
38.9-58.0	Sh	Limited	Saline, sodic
58.0-68.0	Cbsh	Unsuitable	% clay, sodic
68.0-78.5	Sh	Unsuitable	Sodic, pH
78.5-99.2	Cbsh, Ss, Sh	Unsuitable	Sodic, pH
99.2-119.5	Ss	Unsuitable	Sodic, pH
119.5-138.5	Sh	Unsuitable	Sodic, pH
145.0-165.0	Cbsh, Sh	Unsuitable	Sodic, pH
165.0-181.8	Sh, Css	Unsuitable	Sodic, pH
182.0-204.5	Ss	Unsuitable	Sodic, pH

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 79-113

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-28.5	Css, Sh	Unsuitable	Sodic
28.5-53.0	Ssh	Unsuitable	Sodic, pH
63.0-86.8	Sh	Unsuitable	Sodic, pH, Manganese (Mn)
87.6-98.8	Sh, Ss	Unsuitable	Sodic, pH
102.6-113.1	Sh	Unsuitable	Sodic, pH
113.5-127.6	Sh, Ss	Unsuitable	Sodic, pH
129.0-143.0	Css	Unsuitable	Sodic, pH
143.0-160.0	Ss	Unsuitable	Sodic, pH
160.0-174.5	Ss	Unsuitable	Sodic, pH
174.5-200.5	Ss	Unsuitable	Sodic, pH

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 79-114

Depth (ft)	Type	Suitability	Limitig Factor(s)
0.0-10.8	Css	Suitable	-
11.5-25.0	Sh	Limited	Saline
25.0-40.7	Sh	Unsuitable	Sodic
45.4-60.0	Css	Unsuitable	Sodic
60.0-76.0	Css	Unsuitable	Sodic, pH
76.0-90.5	Sh	Unsuitable	Sodic, pH
101.0-121.4	Ssh	Unsuitable	Sodic, pH
123.5-134.5	Ssh,	Unsuitable	Sodic, pH

Suitability of Bedrock Material for Use as Plant Media in Revegetation -
Rattlesnake Butte Study Area
Bedrock Core DH - 79-115

Depth (ft)	Type	Suitability	Limiting Factor(s)
0.0-20.0	Ss	Limited	Sodic
20.0-44.4	Ss	Unsuitable	% sand
44.8-55.5	Ssh	Unsuitable	Sodic
58.2-80.0	Ssh, Ss	Unsuitable	Sodic, pH
80.0-100.0	Ss	Unsuitable	Sodic, pH
100.0-124.5	Ss	Unsuitable	Sodic, pH

Established Series
Rev. FWW-GBM
11/16/78

ARNEGARD SERIES

The Arnegard series consists of deep, well drained soils that formed in calcareous loamy alluvium on upland swales, fans and footslopes. Permeability is moderate. Slopes range from 0 to 9 percent. Mean annual temperature is 42° F, and mean annual precipitation is 14 inches.

Taxonomic Class: Fine-loamy, mixed Pachic Haploborolls.

Typical Pedon: Arnegard loam - cultivated. (Colors are for dry soil unless otherwise stated.)

Ap--0 to 11 inches; dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; weak coarse and medium subangular blocky structure parting to weak fine granular; very friable; many roots; neutral; clear wavy boundary. (8 to 18 inches thick)

B21--11 to 17 inches; dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak coarse and medium prismatic structure parting to moderate fine subangular blocky; few thin clay films on faces of peds; common roots; common pores; neutral; gradual wavy boundary.

B22--17 to 25 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; moderate medium prismatic structure parting to moderate medium and fine angular blocky; friable; few thin clay films on faces of peds; few roots; common pores; neutral; clear wavy boundary. (Combined thickness of the B2 horizon is 8 to 30 inches.)

B3--25 to 32 inches; grayish brown (2.5Y 5/2) loam, very dark grayish brown (2.5Y 3/2) moist; weak coarse prismatic structure parting to weak coarse and medium subangular blocky; friable; neutral; clear wavy boundary. (0 to 10 inches thick)

Clca--32 to 45 inches; light brownish gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; weak coarse and medium subangular blocky structure; friable; few roots; few fine pores; soft bodies of segregated lime; strong effervescence; moderately alkaline; gradual wavy boundary. (7 to 16 inches thick)

C2--45 to 60 inches; light yellowish brown (2.5Y 6/4) loam, light olive brown (2.5Y 5/4) moist; very weak coarse and medium subangular blocky structure; friable; strong effervescence; moderately alkaline.

Type Location: McKenzie County, North Dakota; 300 feet east of the NW corner of sec. 14, T. 150 N., R. 101 W.

Range in Characteristics: The solum thickness ranges from 20 to 58 inches. The mollic epipedon ranges from 16 to more than 30 inches in thickness and includes all or part of the B horizon. The soil typically has segregated or finely divided carbonates within depths of 40 inches but ranges to as deep as 60 inches.

The A horizon has hue of 10YR, value of 3 or 4 and 2 or 3 moist, and chroma of 2. It is loam or silt loam and is slightly acid or neutral. Some pedons have B1 horizons.

The B2 horizon has hue of 10YR or 2.5Y, value of 2 to 4 moist, and chroma of 2 or 3. It is loam, silt loam or light clay loam containing less than 30 percent clay. It is neutral or mildly alkaline.

The Cca horizon has hue of 2.5Y or 10YR, value of 5 to 7 dry and 4 or 5 moist, and chroma of 2 to 4. It is typically loam but includes fine sandy loam to clay loam. It is mildly or moderately alkaline.

The C horizon has hue of 2.5Y or 10YR, value of 5 to 7 dry and 4 or 5 moist, and chroma of 2 to 4. It typically is loam but includes loamy fine sand, fine sandy loam and clay loam. It is neutral to moderately alkaline.

ARNEGARD SERIES--2

Competing Series: These are the Falkirk, Garza, Roseglen and Shawa series in the same family and the Bowbells, Bowdle, Goshen, Grail, Grassna, Mandan, Onita, Parshall, Shambo, Straw and Svea series. Falkirk soils have gravelly loam 11C horizons and glacial till within depths of 40 inches. Garza soils lack cambic horizons. Roseglen soils contain less sand and have formed in lacustrine sediments. Shawa soils lack B horizons and formed in alluvium primarily from igneous rocks. Bowbells soils have argillic horizons. Bowdle soils are fine-loamy over sandy or sandy-skeletal. Goshen and Onita soils have argillic horizons and warmer climates. Grail soils have fine-textured argillic horizons. Grassna soils are fine-silty. Mandan soils are coarse-silty. Parshall soils are coarse-loamy. Shambo soils have mollic epipedons less than 16 inches thick. Straw soils contain carbonates throughout and are stratified. Svea soils have wetter climates.

Geographic Setting: Arnegard soils are on upland swales, fans and footslopes on the residual plains and glacial till plains. They formed in mixed loamy alluvium from calcareous sedimentary rock and glacial till. Slopes typically are 1 or 2 percent but range from 0 to 9 percent. The mean annual temperature is 38 to 45° F, and the mean annual precipitation is 12 to 16 inches, most of which falls during spring and summer.

Geographically Associated Soils: These are the Amor, Farland, Grail, Grassna, Max, Morton, Parshall, Sen, Shambo, Temvik, Vebar and Williams soils. Amor, Morton, Sen and Vebar soils have thinner mollic epipedons formed in residual materials and are on nearby convex slopes. Farland and Shambo soils have thinner mollic epipedons and are on nearby terraces. Max, Williams and Temvik soils have thinner mollic epipedons and formed in glacial till. Grail, Grassna and Parshall soils are in similiar positions.

Drainage and Permeability: Well drained. Runoff is slow or medium. Permeability is moderate.

Use and Vegetation: Most areas are cropped to spring wheat, oats, barley, and hay. Native vegetation is mid, tall and short grasses such as western wheatgrass, green needlegrass, big bluestem and blue grama.

Distribution and Extent: Arnegard soils are extensive and are in western North Dakota, eastern Montana and northwestern South Dakota.

Series Established: McKenzie County, North Dakota, 1937.

Remarks: Soils that formed in loess or similiar silty materials were formerly included in the Arnegard series but now are placed in the Grassna series.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. FWW-GBM
6/18/79

BELFIELD SERIES

The Belfield series consists of deep, well drained slowly permeable soils formed in alkaline, calcareous residuum and alluvium on uplands, terraces, and in swales. Slope ranges from 0 to 9 percent. Mean annual temperature is 43° F, and mean annual precipitation is 15 inches.

Taxonomic Class: Fine, montmorillonitic Glossic Natriborolls.

Typical Pedon: Belfield silty clay loam with a 1 percent slope in native grassland. (Colors are for dry soil unless otherwise stated.)

A1--0 to 9 inches; grayish brown (10YR 5/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium prismatic structure parting to moderate very fine subangular blocky; very hard, friable; many roots; many very fine pores; common uncoated sand grains on faces of peds; slightly acid; clear wavy boundary. (5 to 15 inches thick)

A&B--9 to 12 inches; light brownish gray (2.5Y 6/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium prismatic structure parting to weak medium platy which parts to strong very fine subangular blocky; very hard, friable; many roots; many very fine pores; thin light gray (10YR 7/1) uncoated sand grains on top of plates and discontinuous on bottom of plates; slightly acid; clear smooth boundary. (2 to 5 inches thick)

B21t--12 to 17 inches; grayish brown (2.5Y 5/2) silty clay, very dark grayish brown (2.5Y 3/2) moist; strong medium prismatic structure parting to strong medium and fine angular blocky; extremely hard, friable; common roots; many very fine pores; thin continuous clay films on faces of peds; common uncoated sand grains in the upper part and few in the lower part; neutral; clear wavy boundary.

B22t--17 to 24 inches; light olive brown (2.5Y 5/4) silty clay loam, dark grayish brown (2.5Y 4/2) moist; moderate medium prismatic structure parting t moderate medium and fine subangular blocky; very hard, friable; few roots; many fine pores; tnin clay films of olive brown (2.5Y 4/3) moist; mildly alkaline; clear wavy boundary. (Combined thickness of the B2t is 6 to 24 inches.)

B3ca--24 to 31 inches; grayish brown (2.5Y 5/2) silty clay loam, dark grayish brown (2.5Y 4/2) moist; moderate medium prismatic structure parting to weak medium subangular blocky; very hard, friable; few roots; many fine and very fine pores; common threads of soft lime masses; strong effervescence; moderately alkaline; clear wavy boundary. (4 to 14 inches thick)

C1ca--31 to 43 inches; light brownish gray (2.5Y 6/2) and white (2.5Y 8/2) silty clay loam, dark grayish brown (2.5Y 4/2) and light brownish gray (2.4Y 6/2) moist; weak medium prismatic structure parting to moderate medium subangular blocky; very hard, friable; many fine pores; many threads and films of soft masses; violent effervescence; moderately alkaline; gradual wavy boundary. (0 to 22 inches thick)

C2--43 to 60 inches light olive brown (2.5Y 5/4) clay loam, olive brown (2.5Y 4/4) moist; massive; very hard, friable; many fine pores; violent effervescence; moderately alkaline.

Type Location: Stark County, North Dakota; 320 feet west and 235 feet north of the SE corner of the SW1/4 of sec. 36, T. 137 N., R. 98 W.

Range in Characteristics: The mollic epipedon ranges from 7 to 25 inches in thickness and in many pedons includes all or part of the B horizon. The depth to free carbonates ranges from 20 to 35 inches. The substratum, below depths of 36 inches, typically is alkaline local alluvium or partly weathered siltstone, soft shales, or sandstone. Some pedons have A2 or B&A horizons.

The A horizon has hue of 10YR, value of 4 or 5 dry and 2 or 3 moist and chroma of 2. It commonly is silt loam or silty clay loam, but some is loam or clay loam. It is slightly acid or neutral.

BELFIELD SERIES--2

The B2t horizon has hue of 10YR or 2.5Y, value of 4 to 6 dry and 2 to 5 moist, and chroma of 2 to 4. It is silty clay, silty clay loam, or clay loam averaging 35 to 45 percent clay. Clay films are thin and distinct on faces of peds. It is neutral or mildly alkaline.

The C horizon typically is silty clay loam or clay loam, but some are loam or silty clay. It is moderately or strongly alkaline.

Competing Series: These are the Lennep series in the same family and the Beckton, Cresbard, Daglum, Grail, Niobell, Regent, Rhoades, Savage, Sorum, and Winnett series. Lennep soils have B2t horizons that average 50 to 60 percent clay. Beckton and Winnett soils are mesic. Cresbard soils formed in glacial till and have a more humid climate. Daglum and Rhoades have strong columnar structure, and the Rhoades have visible salts or gypsum within 16 inches of the surface. Grail, Regent, and Savage soils lack natric horizons. Niobell soils formed in glacial till and are fine-loamy. Sorum soils are fine-loamy and have a dryer climate.

Geographic Setting: Belfield soils are on nearly level terraces, upland swales, and on nearly level to moderately sloping uplands. Slopes to 1 to 4 percent are most common, but slopes range 0 to 9 percent. They formed in alkaline, calcareous residuum or alluvium mainly of tertiary origin. Mean annual precipitation ranges from 12 to 16 inches, and mean annual temperature ranges from 38° to 45° F.

Geographically Associated Soils: These are the Amor, Daglum, Farland, Grail, Lawther, Moreau, Morton, Regent, Rhoades, Savage, Sen, and Shambo soils. Amor, Moreau, Morton, Regent, and Sen soils lack natric horizons and are adjacent to Belfield soils on uplands. Daglum and Rhoades soils have strong columnar structure and occupy similar positions as Belfield soils. Farland, Savage, and Shambo soils lack natric horizons and are adjacent to Belfield soils on terraces. Grail and Lawther soils lack natric horizons and are adjacent to Belfield soils on upland swales.

Drainage and Permeability: Well drained. Runoff is slow or medium. Permeability is slow.

Use and Vegetation: Most areas are cropped to small grains. Some are used for hay or pasture. Native vegetation is mid and short prairie grasses such as western wheatgrass, blue grama, and green needlegrass.

Distribution and Extent: Southwestern North Dakota, northwestern South Dakota, and eastern Montana. The soil is extensive.

Series Established: Stark County, North Dakota, 1965.

Additional Data: North Dakota Agricultural Station Laboratory Data Nos. S61ND-45-1, S61ND-45-4, S61ND-45-5, and S61ND-45-9.

National Cooperative Soil Survey
U.S.A.

Replaces Wibanx series

Established Series
Rev. DDO-GBM
12/20/79

BRANDENBURG SERIES

The Brandenburg series are excessively drained soils that are shallow to shattered porcelanite bedrock. They have formed in residuum from porcelanite and have moderate to rapid permeability. Slopes range from 4 to 50 percent. Mean annual precipitation is about 15 inches, and mean annual temperature is about 43°F.

Taxonomic Class: Fragmental, mixed, frigid Typic Ustorthents.

Typical Pedon: Brandenburg channery loam - grassland. (Colors are for dry soil unless otherwise stated.)

A1--0 to 4 inches; pinkish gray (7.5YR 6/2) channery loam, brown (7.5YR 4/2) moist; moderate fine granular structure; slightly hard, very friable; many fine roots; 15 to 30 percent by volume small porcelanite chips; slight effervescence; mildly alkaline; clear wavy boundary. (0 to 6 inches thick)

C1--4 to 10 inches; reddish yellow (5YR 6/6) very channery loam, yellowish red (5YR 4/6) moist; weak medium and fine subangular blocky structure; soft, very friable; over 50 percent by volume porcelanite with thin lime crusts on undersides; strong effervescence; moderately alkaline; clear irregular boundary. (2 to 15 inches thick)

C2--10 to 60 inches; shattered porcelanite which are slightly weathered in upper 2 to 10 inches; strong effervescence; moderately alkaline.

Type Location: Bowman County, North Dakota; about 3 miles east and 1 1/4 miles north of Bowman; 1485 feet north of the SW corner of Sec. 33., T. 132 N., R. 101 W.

Range in Characteristics: The depth to shattered porcelanite or calcareous reddish argillites ranges from 10 to 20 inches. The soil contains more than 35 percent coarse fragments (by volume) although the surface layer in some pedons contains as little as 10 percent. The mean annual soil temperature is estimated to range from 40° to 46°F. The A horizon is loam, gravelly loam, or channery loam. The upper 7 inches when mixed has 7.5YR or redder hue, value of 5 or 6, more than 3.5 moist and chroma of 2 or more. The C1 horizon typically is channery or very channery loam with more than 45 percent by volume of channery material coarser than 2 mm. The underlying material is shattered porcelanite, argillites, or clinkers containing free carbonates.

Competing Series: There are no other series in the same family.

Geographic Setting: The Brandenburg soils are on undulating to steep uplands. Slope gradients range from 4 to 50 percent. The Brandenburg soils formed in residuum containing more than 45 percent by volume of hard porcelanite coarser than 2 mm. The climate is cool, semiarid with cold dry winters and warm moist summers. The mean annual precipitation is 10 to 17 inches, 70 or 80 percent of which falls when the soil is not frozen. The mean annual air temperature is 40 to 45°F.

Geographically Associated Soils: These are the Cabba, Flasher, Ringling, Searing, and Yawdim soils. All these soils are on nearby slopes or hills. Cabba, Flasher, and Yawdim soils are underlain with soft sandstone, siltstone or shale at depths of 8 to 20 inches. Ringling and Searing soils have mollic epipedons. In addition, Searing soils are 20 to 40 inches deep to porcelanite.

Drainage and Permeability: Excessively drained, moderate to rapid permeability. Infiltration rate medium and high. Slow to medium runoff.

Use and Vegetation: Used mainly for range. Native vegetation is threadleaf and needleleaf sedges, short and mid prairie grasses, and creeping cedar and other shrubs.

Distribution and Extent: Widely distributed in sedimentary plains of western North Dakota and eastern Montana. Moderately extensive.

Series Established: Bowman County, North Dakota, 1969.

National Cooperative Soil Survey
U.S.A.

Replaces Bainville series

Established Series
Rev. DRC/SHB
11/76

CABBA SERIES

The Cabba series consists of well drained soils that formed in material weathered from soft sedimentary rock and have sedimentary beds at depths of 8 to 20 inches. Cabba soils are on uplands and are moderately sloping to very steep. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 45°F.

Taxonomic Class: Loamy, mixed (calcareous), frigid, shallow Typic Ustorthents.

Typical Pedon: Cabba cobbly clay loam, native grassland. (Colors are for dry soil unless otherwise noted.)

A1--0 to 2 inches; grayish brown (2.5Y 5/2) cobbly clay loam, grayish brown (2.5Y 4/2) moist; moderate fine crumb structure; slightly hard, friable, slightly sticky and slightly plastic; many fine roots and pores; 15 to 20 percent cobbles, gravel and stones; neutral (pH 7.3); gradual wavy boundary. (2 to 5 inches thick)

AC--2 to 7 inches; grayish brown (2.5Y 5/2) gravelly light clay loam, dark grayish brown (2.5Y 4/2) moist; moderate very fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; 20 percent pebbles; many fine roots and pores; neutral (pH 7.3); gradual wavy boundary. (2 to 10 inches thick)

C1--7 to 18 inches; very pale brown (10YR 7/2) gravelly loam, grayish brown (10YR 5/2) moist; massive; evidence of rock structure in small fragments of weakly consolidated siltstone; slightly hard, friable, nonsticky and slightly plastic; many fine roots and pores; 20 percent pebbles; slightly effervescent; coatings of lime on soft rock fragments; clear wavy boundary. (6 to 15 inches thick)

Cr C2--18 to 60 inches; light gray (10YR 7/2) soft sedimentary bedrock, grayish brown (10YR 5/2) moist; can be chipped out only with a sharp instrument when dry but softens quickly on soaking in water, and becomes material that rubs to a loam texture; roots in cracks and some roots through plates; massive rock; mildly alkaline (pH 7.8.)

Type Location: Granite County, Montana; 1000 feet north and 1500 feet east of the southwest corner of section 35, T.10N., R.12W.

Range in Characteristics: Depth to sedimentary beds is 8 to 20 inches. Mean annual soil temperature ranges from 40° to 47°F. ~~The hue~~ is 10YR or 2.5Y. Rock fragments range from 0 to 35 percent and are mainly of gravel size.

The A horizon has hue of 10YR or 2.5Y, value of 5 or 6 dry, 3 or 4 moist, and chroma of 1 or 2. It ranges from fine sandy loam through silt loam.

The C horizon has hue of 10YR through 5Y, value of 5 through 8 dry, 4 through 7 moist, and chroma of 1 through 3. It is loam, silt loam, silty clay loam or light clay loam and has 20 to 35 percent clay. The underlying sedimentary beds rub to silt loam or loam. This horizon is mildly or moderately alkaline.

Competing Series: These are the Abac and Cohagen series in the same family and the related Cabbart, Kuro, Midway and Wayden series. Abac soils have hue of 5YR or redder. Cabbart soils have an aridic moisture regime that borders on an ustic regime. Cohagen soils have sandy loam C horizons. Kuro soils contain 36 to 45 percent clay. Midway soils have soil temperature warmer than 47°F. Wayden soils have 36 to 50 percent clay.

Geographic Setting: Cabba soils are moderately sloping to very steep and are on uplands at elevations of 2000 to 4800 feet. They formed in material weathered from 12 to 19 inches with areas receiving less than 14 inches having cooler temperatures and lower evaporation. Most of the precipitation falls in the spring and early summer. Mean annual temperature ranges from 41° to 45°F. The (32°F.) growing season is 90 to 135 days.

Geographically Associated Soils: These are the Barvon, Campspass, Farland, Judith, Ringling, Shane and Thebo soils. Barvon soils have a mollic epipedon and are 20 to 40 inches deep to siltstone. Campspass and Farland soils have argillic horizons. Judith soils have a calcareous horizon immediately beneath the mollic epipedon. Ringling soils are fragmental. Shane soils contain more than 60 percent clay. Thebo soils contain more than 35 percent clay.

Drainage and Permeability: Well drained; moderate permeability.

Use and Vegetation: Used for rangeland. Native plants are bluebunch wheatgrass, little bluestem, needleandthread, western wheatgrass, green needlegrass, annual, and low-density stands of ponderosa pine.

Cabba Series

Distribution and Extent: Widely distributed in Montana. Cabba soils are of moderate extent.

Series Established: Granite County, Montana, 1969.

Remarks: The nature of the sedimentary beds is currently under study. The classification of the series may need to be changed if these soils lack a paralithic contact at shallow depth.

National Cooperative Soil Survey
U. S. A.

Established Series
Rev. RLM-GBM
6/3/80

CHAMA SERIES

The Chama series consists of well drained soils formed in materials weathered from soft siltstone and shale on uplands. These soils are moderately deep to soft siltstone or shale. These soils are moderately or moderately slowly permeable. Slopes range from 0 to 35 percent. Mean annual temperature is 42° F, and mean annual precipitation is 15 inches.

Taxonomic Class: Fine-silty, mixed Entic Haploborolls.

Typical Pedon: Chama silt loam on an 8 percent south-southeast-facing slope in a pasture. (When described, the soil was dry throughout. Colors are for dry soil unless otherwise stated.)

A1--0 to 4 inches; grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak medium and fine subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; neutral; abrupt smooth boundary. (3 to 7 inches thick)

B2--4 to 8 inches; grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium prismatic structure parting to moderate medium subangular blocky; slightly hard, friable, slightly sticky and nonplastic; slight effervescence; mildly alkaline; clear smooth boundary. (2 to 7 inches thick)

B3ca--8 to 13 inches; light gray (2.5Y 7/2) silt loam, light olive brown (2.5Y 5/4) moist; weak medium prismatic structure parting to moderate medium and fine subangular blocky; slightly hard, friable, slightly sticky and nonplastic; many fine lime masses; violent effervescence; mildly alkaline; clear smooth boundary. (0 to 8 inches thick)

C1ca--13 to 22 inches; light yellowish brown (2.5Y 6/4) silt loam, olive brown (2.5Y 4/4) moist; weak medium subangular blocky and weak thick platy structure; slightly hard, friable, slightly sticky and nonplastic; many medium lime masses; violent effervescence; mildly alkaline; clear smooth boundary. (4 to 20 inches thick)

C2ca--22 to 34 inches; light yellowish brown (2.5Y 6/4) silt loam, light olive brown (2.5Y 5/4) moist; massive; slightly hard, friable, slightly sticky and nonplastic; many large lime concretions; slight effervescence; mildly alkaline; gradual wavy boundary. (0 to 14 inches thick)

Cr--34 to 60 inches; pale yellow (2.5Y 7/4) soft siltstone, light olive brown (2.5Y 5/4) moist; slight effervescence; mildly alkaline.

Type Location: Slope County, North Dakota; 1,180 feet north and 1,420 feet east of the southwest corner, sec. 15, T. 136 N., R. 99 W.

Range in Characteristics: Thickness of solum ranges from 12 to 22 inches. Depth to soft bedrock ranges from 20 to 40 inches. The mollic epipedon ranges from 7 to 10 inches thick.

The A horizon has hue of 10YR or 2.5Y, value of 3 to 5 and 2 or 3 moist, and chroma of 2. It is silt loam, silty clay loam, or loam. It is neutral to mildly alkaline.

The B2 horizon has hue of 2.5Y or 10YR, value of 4 to 6 and 3 or 4 moist, and chroma of 2. It is silt loam or silty clay loam. It is calcareous throughout and is mildly alkaline or moderately alkaline.

The C horizon is silt loam or silty clay loam. It is mildly alkaline or moderately alkaline.

Competing Series: There are no other series in the same family. Other competing series are the Bryant, Cabba, Cambert, Cherry, Floweree, Golva, Omio, Peritsa, Sen, and Temvik series. Bryant, Cherry, Golva, and Temvik soils lack soft siltstone within 40 inches. Sen and Omio soils have noncalcareous B2 horizons. Omio soils have a solum formed in loess. Peritsa soils have hue redder than 7.5YR in the solum. Cabba soils have soft bedrock at depths less than 20 inches. Cambert soils lack mollic epipedons. The Floweree soils have an aridic moisture regime.

CHAMA SERIES--2

Geographic Setting: Chama soils are on nearly level to steep uplands. Slope gradients are commonly 3 to 15 percent but range from 0 to 35 percent. The soils formed in materials weathered from soft siltstone and shale. The mean annual temperature is 42° to 44° F, and the mean annual precipitation is 14 to 17 inches.

Geographically Associated Soils: These are the competing Cabba, Golva, and Sen soils and the Grassna, Morton, and Reeder soils. The Cabba soils are on knobs and steeper landscapes. The Golva and Grassna soils are in the lower lying positions. Sen soils are on similar landscapes. Morton and Reeder soils are on similar positions but have argillic horizons.

Drainage and Permeability: Well drained. Runoff is medium to rapid. Permeability is moderate or moderately slow.

Use and Vegetation: Soils are cropped to small grains, which are mostly wheat; a significant acreage is in rangeland. The native vegetation is principally western wheatgrass, needleandthread, and blue grama.

Distribution and Extent: Western North Dakota, eastern Montana and possibly northwestern South Dakota. The series is of moderate extent.

Series Established: Wibaux County, Montana, 1956.

Remarks: The soil was formerly classified as fine-silty, mixed Typic Haploboroll.

National Cooperative Soil Survey
U.S.A.

Replaces Beckton series

Established Series
Rev. SPB
11/8/78

DAGLUM SERIES

The Daglum series consists of deep, moderately well and well drained soils formed in clayey alluvium terraces, foot slopes, and swales in uplands. These soils have very slow permeability. Slopes range from 0 to 9 percent. Mean annual temperature is about 42° F, and the mean annual precipitation is about 14 inches.

Taxonomic Class: Fine, montmorillonitic Typic Natriborolls.

Typical Pedon: Daglum clay loam - on a level terrace having less than 1 percent slope in native grassland. (Colors are for dry soil unless otherwise stated. Where described the soil was dry to a depth of 18 inches and moist below 18 inches.)

A1--0 to 5 inches; dark grayish brown (10YR 4/2) clay loam, very dark brown (10YR 2/2) moist; moderate medium prismatic structure parting to moderate medium subangular blocky and weak fine platy; hard, friable, sticky, slightly plastic; many fine roots and pores; thin light gray (10YR 6/1) patches of sand grains on plates; slightly acid; clear irregular boundary. (4 to 15 inches thick)

A2--5 to 8 inches; grayish brown (10YR 5/2) light clay loam, very dark grayish brown (10YR 3/2) moist; light gray (10YR 6/1) bleached sand grains in thick patches; weak medium prismatic structure parting to moderate medium and fine platy; hard, very friable, slightly sticky, slightly plastic; common roots, many fine pores; slightly acid; clear wavy boundary. (1 to 5 inches thick)

B21t--8 to 13 inches; grayish brown (10YR 5/2) clay, very dark grayish brown (10YR 3/2) moist; strong medium and fine columnar structure; extremely hard, firm, very sticky, plastic; few roots, common fine pores, thin clay films on sides of columns; light gray (2.5Y 7/1) bleached films on tops of columns; mildly alkaline; gradual boundary.

B22t--13 to 18 inches; grayish brown (10YR 5/2) clay, dark grayish brown (10YR 4/2) moist; moderate coarse prismatic structure parting to strong medium and fine angular blocky; extremely hard, firm, very sticky, plastic; few roots; films of very dark grayish brown (10YR 3/2) moist, coat the faces of the prisms and blocks; moderately alkaline; clear irregular boundary. (Combined B2 horizons 7 to 16 inches thick)

C1cs--18 to 26 inches; light yellowish brown (2.5Y 6/3) silty clay, light olive brown (2.5Y 5/4) moist; common fine distinct mottling of very dark grayish brown (10YR 3/2) moist; weak coarse and medium subangular blocky structure; very hard, friable, sticky, plastic; common white salt crystals; slight effervescence; strongly alkaline; gradual wavy boundary. (0 to 10 inches thick)

C2--26 to 45 inches; light gray (5Y 6/1) silty clay, dark gray (5Y 4/1) moist; many fine distinct dark grayish brown mottles (2.5Y 4/2) moist; massive; very hard, firm, sticky plastic; few to common fine salt accumulations; slight effervescence; strongly alkaline; gradual boundary. (0 to 24 inches thick)

Cr--45 to 60 inches; light gray (5Y 6/1) soft platy shale which is silty clay when crushed, dary gray (5Y 4/1) moist; abundant salt crystals; slight effervescence; moderately alkaline.

Type Location: Stark County, North Dakota; about 13 miles south and 4 miles west of Dickinson; 765 feet east and 360 feet south of the NW corner of sec. 24, T. 137 N., R. 97 W.

Range in Characteristics: The thickness of the solum typically is 16 to 24 inches, but ranges from 12 to 32 inches. The depth to soft shales is greater than 40 inches.

The A1 horizon has hue of 10YR, value of 4 or 5 and 2 or 3 moist, and chroma of 2 dry or moist. It typically is clay loam or silty clay loam, but some is fine sandy loam, silt loam, loam, or silty clay.

The A2 horizon has hue of 10YR or 2.5Y, value of 4 through 7 and 3 through 5 moist, and chroma of 1 or 2 dry or moist. It is very fine sandy loam, loam, silt loam, clay loam, or silty clay loam. It has weak prismatic or blocky structure parting to weak or moderate, medium or fine platy structure.

The B2t horizon has hue of 10YR or 2.5Y, value of 4 through 6 and 3 through 5 moist, and chroma of 2 or 3 dry or moist. It is clay, silty clay, silty clay loam, or clay loam containing 35 to 60 percent clay. It has strong columnar structure in the upper part grading to moderate or strong prismatic and blocky structure in the lower part. The B2 horizon ranges from neutral to moderately alkaline in the upper part and mildly to strongly alkaline in the lower part. The exchangeable sodium exceeds 15 percent or the sodium plus magnesium exceeds calcium plus hydrogen. Salt crystals and some carbonate accumulations are in the lower part in some pedons. Some pedons have buried A horizons.

The C horizon has hue of 2.5Y or 5Y, value of 5 through 7 and 3 through 6 moist, and chroma of 1 through 4 dry or moist. It is clay loam, silty clay, silty clay loam, or clay, and is stratified in some pedons. Soft sedimentary beds of shale, siltstone or fine grained sandstone are in some pedons at depth below 40 inches.

Competing Series: These are the Adger series in the same family and the Belfield, Cavour, Demers, Desart, Ekalaka, Haccke, Hapney, Harriet, Larson, Noonan, Rhoades and Sorum series. Adger soils have strongly alkaline A horizons. Belfield soils have interfingering of an A and B horizon into the B2t horizon and lack strong columnar structure. Cavour, Harriet, and Larson soils have A1 horizons with chroma of 1 and are usually moist. Harriet soils are poorly drained. Demers and Haccke soils have fine-silty textures. Desart, Ekalaka, Noonan and Sorum soils contain less clay and more sand. In addition, Noonan soils, formed in till and contain coarse fragments. Hapney soils lack A1 horizons and have A2 horizons less than 2 inches thick and in addition are drier. Rhoades soils have thinner sola and A horizons less than 5 inches thick.

Geographic Setting: Daglum soils are on nearly level terraces, foot slopes, swales and undulating upland plains. Slope gradients range from 0 to over 9 percent. The soils formed in clayey alluvium. The mean annual temperature ranges from 40 to 45° F, and mean annual precipitation from 12 to 16 inches. Moist of the precipitation comes in the spring and summer.

Geographically Associated Soils: These are the competing Belfield and Rhoades soils and the Absher, Farland, Grail, Lawther, Moreau, Morton, Reeder, Regent, Savage, and Shambo soils. Belfield and Rhoades soils are in complex with Daglum series in many areas. Absher soils lack a mollic epipedon. All other soils lack natric horizons. They are on nearby terraces and uplands.

Drainage and Permeability: Moderately well and well drained. Runoff is slow or medium. Permeability is very slow.

Use and Vegetation: Used for range, pasture and small grains. Native vegetation is western wheatgrass, bluegrama, green needlegrass, needleleaf sedge and forbs.

Distribution and Extent: Western North Dakota, northwestern South Dakota, and eastern Montana. The soil is of moderate extent.

Series Established: Bowman County, North Dakota, August 1969.

Remarks: The Daglum series would have been classified solodized-Solonetz in the former system.

Additional Data: North Dakota Agr. Exp. Sta. laboratory data number S62ND-45-1.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. SRE
12/8/78

FARLAND SERIES

The Farland series consists of deep, well drained soils that formed in stratified alluvium on terraces and valley footslopes. Permeability is moderate or moderately slow. Slopes range from 1 to 9 percent. Mean annual precipitation is about 14 inches, and mean annual temperature is about 42° F.

Taxonomic Class: Fine-silty, mixed Typic Argiborolls.

Typical Pedon: Farland silt loam on an east facing 1 percent slope in native grassland. (Colors are for dry soil unless otherwise stated. When described, the soil was moist to 13 inches and dry below.)

A1--0 to 4 inches; dark grayish brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) moist; weak medium and fine prismatic and fine subangular blocky structure parting to moderate fine granular; slightly hard, friable; many roots; many fine pores; neutral; gradual wavy boundary. (3 to 12 inches thick)

B21t--4 to 11 inches; grayish brown (10YR 5/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine prismatic structure parting to strong medium and fine angular blocky; hard, friable; many roots; common fine pores; thin clay films on faces of peds; neutral; clear wavy boundary.

B22t--11 to 18 inches; grayish brown (2.5Y 5/2) silty clay loam, dark grayish brown (2.5Y 4/2) moist; moderate medium and fine prismatic structure parting to strong medium and fine subangular blocky; hard, friable; common roots; common fine pores; thin patchy clay films; neutral; gradual wavy boundary. (Combined thickness of B2 horizons 8 to 22 inches)

B3--18 to 25 inches; light yellowish brown (2.5Y 6/4) silt loam, grayish brown (2.5Y 5/2) moist; weak coarse prismatic and moderate coarse subangular blocky structure; hard, friable; few roots; common fine pores; strong effervescence; mildly alkaline; clear wavy boundary. (0 to 15 inches thick)

C1ca--25 to 34 inches; light yellowish brown (2.5Y 6/4) loam, light olive brown (2.5Y 5/4) moist; weak coarse prismatic and moderate coarse and medium subangular blocky structure; friable; few roots; few fine pores; violent effervescence with common coarse masses of soft lime; moderately alkaline; gradual boundary. (7 to 20 inches thick)

C2--34 to 60 inches; light brownish gray (2.5Y 6/2) stratified silt loam, loam and silty clay loam, olive brown (2.5Y 4/4) moist; weak coarse to fine subangular blocky structure parting to weak thin platy; friable; few roots; few fine pores; strong effervescence; moderately alkaline.

Type Location: Stark County, North Dakota; about 10 miles east of Richardton; 1,490 feet north and 1,200 feet west of SE corner, sec. 1, T. 139 N., R. 91 W.

Range in Characteristics: The solum thickness ranges from 12 to 36 inches and depth to free lime ranges from 8 to 30 inches. The profile is more than 40 inches thick to a paralithic contact or contrasting substratum. The mollic epipedon ranges from 8 to 16 inches in thickness.

The A horizon has 10YR hue, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3. It is loam, silt loam or light clay loam.

The B2t horizon has 10YR or 2.5Y hue, value of 4 through 6 and 3 or 4 moist, and chroma of 2 to 4. It is silty clay loam, clay loam having a clay content which averages between 27 and 35 percent. Structure ranges from moderate to strong prismatic which parts to strong or moderate angular or subangular blocks. Peds in this horizon have thin continuous or patchy clay films.

The Cca horizon contains both diffuse and segregated soft masses of lime. The lower C horizon is typically loam, silt loam or silty clay loam alluvium, and less commonly stratified silt, silty clay, very fine sandy loam and very fine sand.

FARLAND SERIES--2

Competing Series: These are the Jekley, Morton and Xavier series of the same family and the Agar, Arnegard, Belfield, Brusset, Farnuf, Grail, Savage, Sen, Shambo, Straw and Williams series. The Jekley and Morton soils have bedrock within depths of 40 inches. Jekley soils, in addition, occur at elevations above 7,700 feet. Xavier soils have thinner sola. Agar soils are mesic. Arnegard, Sen, Shambo and Straw soils lack argillic horizons. Arnegard and Straw soils, in addition, have mollic epipedons more than 16 inches thick. The Belfield soils have thin albic horizons, natric horizons, and are in the fine family. Brusset soils have lighter colored A horizons and thinner mollic epipedons. Farnuf and Shambo soils are fine-loamy. Grail soils have mollic epipedons more than 16 inches thick and are in the fine family. The Savage soils are in the fine family. Williams soils are formed in glacial till and are fine-loamy.

Geographic Setting: Farland soils are on nearly level to gently sloping terraces and footslopes of stream valleys. Slope gradients commonly average between 1 and 6 percent, but range from 0 to 9 percent. The soils formed in stratified alluvium of mixed mineralogy which contains little fine and coarser sand. The climate is cool, semiarid, with a mean annual temperature ranging from 38 to 45° F, and a mean annual precipitation from 12 to 16 inches. Most of the precipitation comes in the spring and summer.

Geographically Associated Soils: Belfield, Manning, Parshall, Savage, Shambo, Stady and Straw soils are on adjacent terraces. Manning and Stady soils have gravelly IIC horizons at less than 40 inches. Straw soils are on low terraces subject to flooding. Soils on adjacent uplands are Morton, Regent, Sen and Vebar.

Drainage and Permeability: Well drained. Runoff is slow or medium. Permeability is moderate or moderately slow.

Use and Vegetation: Cultivated areas are used for growing small grains, flax, corn, hay and pasture. Some areas are irrigated for production of alfalfa, beans, corn, and sugar beets. Native vegetation is mid and short prairie grasses as green needlegrass, western wheatgrass and blue grama.

Distribution and Extent: Western North Dakota, eastern Montana and northwestern South Dakota. The series is of moderate extent.

Series Established: McKenzie County, North Dakota, 1932.

Remarks: The series was classified Chestnut in the former system.

Additional Data: S58ND-45-13, and S58ND-45-20 on pp. 88-91 of Soil Survey Investigation Report No. 2.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. SRF
12/8/78

FLASHER SERIES

The Flasher series consists of shallow, somewhat excessively drained soils formed in materials from soft sandstone on upland ridgetops and sideslopes. Permeability is moderately rapid or rapid. Slopes range from 3 to 50 percent. Mean annual precipitation is about 14 inches and mean annual temperature is about 42° F.

Taxonomic Class: Mixed, frigid, shallow Typic Ustipsamments.

Typical Pedon: Flasher loamy fine sand - grassland. (Colors are for dry soil unless otherwise stated.)

A1--0 to 6 inches; dark grayish brown (10YR 4/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky and very weak medium granular structure; very friable; many roots; quartz grains stained; slight effervescence; mildly alkaline; gradual wavy boundary. (4 to 8 inches thick)

C--6 to 10 inches; light olive brown (2.5Y 5/4) loamy fine sand, olive brown (2.5Y 4/4) moist; very weak fine subangular blocky structure; loose; common roots; few small hard sandstone fragments; slight effervescence; mildly alkaline; gradual smooth boundary. (3 to 12 inches thick)

Cr1--10 to 24 inches; light yellowish brown (2.5Y 6/4) soft sandstone which crushes to loamy fine sand, olive brown (2.5Y 4/4) moist; massive; loose; few roots; few hard sandstone fragments; slight effervescence; moderately alkaline; gradual wavy boundary. (0 to 20 inches thick)

Cr2--24 to 60 inches; light yellowish brown (2.5Y 6/4) and pale yellow (2.5Y 7/4) soft sandstone, light olive brown (2.5Y 5/4) moist; massive; slight effervescence.

Type Location: Grant County, North Dakota; about 11 miles W of town of Flasher, 1/4 mile N of SE corner sec. 3, T. 134 N., R. 86 W.

Range in Characteristics: The depth to soft sandstone typically is 10 to 20 inches and ranges from 7 to 20 inches. The control section typically is loamy fine sand, and range includes fine sand, loamy sand and sand. It ranges from neutral to moderately alkaline and commonly contains free carbonates.

The A1 horizon has hue of 10YR or 2.5Y, rarely 7.5YR, value of 4 through 6 and 2 through 4 moist, and chroma of 2 or 3 dry or moist. It typically is loamy fine sand, but some is loamy sand, fine sand, sandy loam or fine sandy loam. Those with sandy loam and fine sandy loam textures have loamy fine sand, loamy sand or fine sand in more than half of the control section.

The C horizon has hue of 2.5Y, 5Y or 10YR, value of 4 through 8 and 3 through 6 moist and chroma of 2 through 4 dry or mosit. It is loamy fine sand, fine sand or loamy sand.

The sandstone typically is slightly hard or hard and brittle when dry and soft when moist. It crushes easily to fine sand or loamy fine sand. Some pedons have hard layers of iron oxide. In some places cylindrical and spherical concretions of hard sandstone are in the soft sandstone.

Competing Series: There are no other series in the family. Other competing series are the Blanchard, Claire, Cohagen, Dast, Dwyer, Fleak, Lihen, Serden, Seroco, Telfer, Tullock, Tusler, Vebar, Yetull, and Zeona series. Blanchard, Claire, Lihen, Serden, Seroco, Telfer, Yetull and Zeona soils all lack soft sandstone within the control section. In addition Claire and Yetull soils contain medium and coarse sands; Lihen and Telfer soils have mollic epipedons; and Zeona soils are usually dry. Cohagen and Dast soils are coarse-loamy. Dwyer and Tullock soils have mesic temperatures. Fleak and Tusler soils are usually dry. Vebar soils have B2 horizons and in addition are underlain by soft sandstone at depths of 20 to 40 inches.

FLASHER SERIES--2

Geographic Setting: Flasher soils are on crests of hills, ridges, and steep sides of valleys in uplands. Slope gradients range from 3 percent to 50 percent. The soils formed in soft sandstone. The climate is cool, semiarid. The mean annual temperature ranges from 38 to 45° F and the mean annual precipitation from 12 to 16 inches. Most of the moisture falls in the spring and summer.

Geographically Associated Soils: These are the competing Cohagen, Lihen, Seroco, Telfer, and Vebar soils and the Amor, Arnegard, Cabba, Morton, Parshall, Reeder, Tally and Werner soils. Cohagen soils are on similiar landscapes as the Flasher soils but have formed in sandstone containing more silt and clay. Lihen, Seroco and Telfer soils are on nearby terraces and uplands. Vebar soils are on less sloping uplands. Amor, Arnegard, Morton, Parshall, Reeder, and Tally soils are on nearby less sloping terraces and uplands. They all lack sandstone at shallow depths, and all have mollic epipedons. Cabba and Werner soils are on hills and steep slopes similiar to Flasher soils, but Cabba soils have loamy textures and Werner soils have loamy textures and mollic epipedons.

Drainage and Permeability: Somewhat excessively drained. Permeability is moderately rapid or rapid. Runoff is slow or medium.

Use and Vegetation: Used mainly for range and pasture. Native vegetation is prairie sandreed blue grama, little bluestem, upland sedges, some creeping cedar, and other shrubs.

Distribution and Extent: Western North Dakota, northwestern South Dakota and eastern Montana. The soil is of large extent.

Series Established: McKenzie County, North Dakota, 1932.

Remarks: The Flasher soils were formerly classified as Regosols.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. GBM
11/9/79

GRAIL SERIES

The Grail series consists of deep, well drained, moderately slow or slowly permeable soils that formed in alluvium. These soils are on upland swales, fans, and foot slopes and have slopes ranging from 0 to 9 percent. Mean annual temperature is 42°F, and mean annual precipitation is 15 inches.

Taxonomic Class: Fine, montmorillonitic Pachic Argiborolls.

Typical Pedon: Grail silt loam - cultivated. (Colors are for dry soil unless otherwise stated.)

Ap--0 to 5 inches; dark grayish brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) moist; weak coarse and medium subangular blocky structure; soft, friable, many roots; many pores; neutral; abrupt boundary.

A12--5 to 10 inches; dark gray (10YR 4/1) silt loam, very dark brown (10YR 2/2) moist; weak medium prismatic structure parting to moderate coarse and medium subangular blocky; slightly hard, friable; many roots; many pores; neutral; gradual wavy boundary. (Combined A horizon 5 to 15 inches thick)

B1--10 to 13 inches; dark gray (10YR 4/1) silty clay loam, very dark brown (10YR 2/2) moist; weak medium prismatic parting to moderate coarse and medium subangular blocky parting to moderate fine granular; firm; common roots; few pores; fine clay films on prisms and blocks; neutral; gradual boundary. (0 to 6 inches thick)

B2t--13 to 24 inches; grayish brown (10YR 5/2) silty clay, very dark grayish brown (10YR 3/2) moist; moderate coarse prismatic structure parting to strong medium and fine angular blocky; very hard, firm; few roots; few pores; clay films on all peds; neutral; clear wavy boundary. (9 to 22 inches)

C1ca--24 to 52 inches; light brownish gray (2.5Y 6/2) silty clay loam, grayish brown (2/5Y 5/2) moist; very weak medium prismatic structure parting to moderate coarse and medium subangular blocky; hard, firm; few pores; strong effervescence; few small bodies of powdery lime, moderately alkaline; clear wavy boundary. (7 to 36 inches thick)

C2--52 to 60 inches; grayish brown (2.5Y 5/2) silty clay loam, dark grayish brown (2/5Y 4/2) moist; weak medium blocky structure; hard, firm; strong effervescence; few small bodies of segregated lime; moderately alkaline.

Type Location: Stark County, North Dakota, 900 feet west and 900 feet south of the center of sec. 18, T. 139 N., R. 91 W.; 35 feet north of old county road.

Range in Characteristics: The thickness of the solum ranges from 20 inches to more than 42 inches. The mollic epipedon is more than 16 inches thick and includes all of the A horizon and all or part of the B horizon. Some pedons have buried A horizons.

The A horizon has 10YR hue, value of 2 or 3 moist, and chroma of 1 or 2. It is silt loam, silty clay loam, or clay loam. It is slightly acid to neutral.

The B2t horizon has hue of 10YR or 2.5Y, value of 2 through 4 moist, and chroma of 1 through 3. It is silty clay, silty clay loam, clay, or clay loam. Some pedons have a B3 or B3ca horizon. The B2t horizon averages between 35 and 45 percent clay.

The C horizon has hue of 2.5Y, value of 3 to 5 moist. It is loam, silt loam, silty clay loam, clay loam, or clay. It commonly contains less than 15 percent $CaCO_3$ equivalent which is both diffused and in segregated bodies. It is mildly alkaline to moderately alkaline. Soft bedrock is below 40 inches in some pedons.

Competing Series: These are the Fughes, Hillery, Kubler, and Zoltay in the same family and the Arnegard, Belfield, Bowbells, Grassna, Lawther, Norton, Promise, Regent, and Savage series. Fughes and Hillery soils lack horizons of $CaCO_3$ accumulation about 60 inches; in addition, Hillery soils have greater than 50 percent clay in the control section. Kubler soils have color hues of 7.5YR and redder. Zoltay soils contain more than 15 percent rock fragments. Arnegard, Grassna and Lawther soils lack an argillic horizon; in addition, Arnegard soils are fine-loamy, Grassna soils are fine-silty, and Lawther soils have more clay and have a calcareous solum. Belfield soils have natric horizons. Bowbells soils are fine-loamy. Morton, Regent, and Savage soils have mollic epipedons less than 16 inches thick; in addition, Morton and Regent soils have soft bedrock within 40 inches. Promise soils are mesic and very fine.

Geographic Setting: Grail soils are on slightly concave upland swales, terraces, alluvial fans, and foot slopes. Slope gradients typically are 1 to 3 percent but range from 0 to 9 percent. The soils formed in local alluvium originating mainly from silty and clayey soft sedimentary bedrock. Mean annual temperature is 38 to 45°F, and mean annual precipitation is 12 to 16 inches.

Geographically Associated Soils: These are the Amor, Arnegard, Belfield, Cabba, Daglum, Farland, Lawther, Morton, Regent, Rhoades, Savage, Sen, Vebar, and Williams. Amor, Morton, Sen, and Vebar soils have soft sedimentary bedrock at depths of 20 to 40 inches and are on adjacent upland convex slopes. Arnegard soils are fine-loamy and are on similar positions as Grail soils. Belfield, Daglum, and Rhoades soils have natric horizons and are on similar positions as Grail soils. Cabba soils have soft sedimentary bedrock within 20 inches, have steeper slopes and are on adjacent upland convex slopes. Farland soils are typically on terraces and are fine-silty. Lawther soils have more clay and are on similar positions as Grail soils. Regent soils have soft swales within depths of 40 inches and are on adjacent upland convex slopes. Savage soils have mollic epipedons less than 16 inches in thickness and typically are on terraces. Williams soils are fine-loamy and formed in glacial till.

Drainage and Permeability: Well drained. Runoff is slow or medium. Permeability is moderately slow or slow.

Use and Vegetation: Most areas are used for cultivated crops such as wheat, oats, and barley. Native vegetation includes mixed grasses such as western wheatgrass, big bluestem, green needlegrass, and needleandthread.

Distribution and Extent: Western North Dakota, northwestern South Dakota, and eastern Montana. The soil is of large extent.

Series Established: McKenzie County, North Dakota, 1932.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. AAA/SHB
11/76

HAVRE SERIES

The Havre series consists of deep, well drained soils that formed in stratified alluvium. Havre soils are on stream terraces and floodplains and are nearly level to moderately sloping. The mean annual precipitation is about 12 inches, and the mean annual air temperature is about 41°F.

Taxonomic Class: Fine-loamy, mixed (calcareous), frigid Ustic Torrifluvents.

Typical Pedon: Havre loam, cultivated. (Colors are for dry soil unless otherwise noted.)

Ap--0 to 8 inches; grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; weak granular structure; soft, very friable, slightly sticky and slightly plastic; moderately effervescent; moderately alkaline; abrupt wavy boundary. (5 to 10 inches thick)

C1--8 to 36 inches; light brownish gray (2.5Y 6/2) loam with thin lenses of fine sandy loam, dark grayish brown (2.5Y 4/2) moist; massive; slightly hard, very friable, slightly sticky and slightly plastic; common fine roots; common to many medium and fine pores; strongly effervescent; moderately alkaline (pH 8.2); clear wavy boundary. (18 to 30 inches thick)

C2--36 to 60 inches; light brownish gray (2.5Y 6/2) loam with thin lenses of fine sandy loam and silt loam, dark grayish brown (2.5Y 4/2) moist; massive; slightly hard, very friable, slightly sticky and nonplastic; few fine and very fine roots; common medium and fine pores; strongly effervescent; moderately alkaline (pH 8.2).

Type Location: Blaine County, Montana; 1,050 feet north and 2,640 feet east of SW corner of section 33, T.32N., R.23E.

Range in Characteristics: Mean annual soil temperature is 41° to 47°F. Hue is 10YR or 2.5Y, value is 5 or 6 dry, 4 or 5 moist, and chroma is 2 or 3 throughout the soil. The 10- to 40-inch control section is typically stratified loam and fine sandy loam and averages 20 to 30 percent clay and 15 to 35 percent coarser than very fine sand. The principal surface textures are loam, clay loam, silt loam, silty clay loam and silty clay. Some pedons have 1/2- to 3-inch thick lenses of either coarser or finer material. Gravelly substrata occur below depths of 40 inches in some pedons. Reaction is mildly or moderately alkaline.

Competing Series: These are the Benz series in the same family and the Havrelon, Hysham, and Haverson series. Benz soils have more than 15 percent exchangeable sodium throughout. Havrelon soils have an ustic moisture regime. Haverson and Hysham soils have annual soil temperature of 47° to 59°F.

Geographic Setting: Havre soils are nearly level to moderately sloping and are on floodplains and stream terraces at elevations of 2,000 to 3,500 feet. They formed in calcareous stratified loamy alluvium. Mean annual temperature is 38° to 46°F; mean January temperature is 5° to 20°F., and mean July temperature is 65° to 70°F. Annual precipitation is 10 to 14 inches, most of which falls during the spring and early summer. The (32°F.) growing season is 90 to 135 days.

Geographically Associated Soils: These are the Bowdoin, Glendive, Harlem, and Wolf Point soils. Bowdoin soils have a very-fine control section. Glendive soils have a coarse-loamy control section. Harlem and Wolf Point soils have a fine control section.

Drainage and Permeability: Well drained; slow runoff; moderate permeability.

Use and Vegetation: These soils are used mainly for irrigated cropland and hayland. Native plants are western wheatgrass, bluebunch wheatgrass, green needlegrass, prairie junegrass, needleandthread, blue grama, sagebrush and low density stands of cottonwood trees.

Distribution and Extent: Northern and central Montana. The soils are extensive.

Series Established: Milk River Area, Montana, 1928.

National Cooperative Soil Survey
U.S.A.

Replaces Hoven series

Established Series
Rev. GBM
12/8/78

HEIL SERIES

The Heil series consists of deep, poorly drained, very slowly permeable soils that formed in clayey, calcareous alluvium. Slopes are less than 1 percent. Mean annual temperature is 43° F, and mean annual precipitation is 15 inches.

Taxonomic Class: Fine, montmorillonitic, frigid Typic Natraquolls.

Typical Pedon: Heil silty clay in native grassland. (Colors are for moist soil unless otherwise stated.)

A2--0 to 3 inches; dark gray (10YR 4/1) silty clay, light gray (10YR 6/1) dry; common fine prominent brown (10YR 5/3) and dark brown (10YR 4/3) mottles; moderate fine subangular blocky and weak fine platy structure; firm; many roots and fine pores; neutral; abrupt wavy boundary. (1 to 4 inches thick)

B21t--3 to 7 inches; very dark gray (2.5Y 3/1) silty clay, gray (2.5Y 5/1) dry; strong coarse and medium columnar structure parting to strong coarse medium and fine angular; extremely hard, very firm; roots in cracks and blocks, few pores; mildly alkaline; gradual smooth boundary.

B22t--7 to 24 inches; very dark gray (5Y 3/1) silty clay, gray (5Y 5/1) dry; strong very coarse prismatic structure parting to strong coarse and medium angular blocky; extremely hard, very firm; few roots; surface of peds have a glossy appearance when moist; few tongues of A2 (5Y 6/1) dry; moderately alkaline; gradual wavy boundary. (Combined thickness of the B2 horizon is 6 to 28 inches)

B3--24 to 38 inches; dark gray (5Y 4/1) silty clay, light gray (5Y 6/1) dry; moderate coarse angular blocky structure; extremely hard, very firm; strong effervescence; moderately alkaline; gradual wavy boundary. (0 to 17 inches thick)

C1g--38 to 44 inches; dark gray (5Y 4/1) silty clay, light gray (5Y 6/1) dry; weak coarse and fine angular blocky structure; very firm, few fine gypsum crystals; strong effervescence; moderately alkaline; diffuse boundary. (2 to 10 inches thick)

C2g--44 to 52 inches; olive (5Y 4/3) silty clay, pale olive (5Y 6/3) dry; weak coarse subangular blocky structure; very firm; common gypsum crystals; strong effervescence; strongly alkaline; gradual boundary. (8 to 20 inches thick)

C3g--52 to 60 inches; olive (5Y 5/4) silty clay, pale olive (5Y 6/3) dry; many mottles of strong brown (7.5YR 5/6), yellowish brown (10YR 5/6) and gray (5Y 5/1); massive few large white soft masses of lime nodules; strong effervescence; strongly alkaline.

Type Location: Slope County, North Dakota; about 6 miles east and 2 miles north of Amidon; 650 feet west and 20 feet south of the NE corner of sec. 14, T. 135 N., R. 100 W.

Range in Characteristics: Depth to carbonates range from 15 to 38 inches. Some pedons have A1 horizons 1 to 3 inches thick. Total thickness of entire A1 and A2 horizons ranges from 1 to 4 inches. Visible salts are in the B3 and Cg horizons of some pedons.

The A2 horizon has hue of 10YR, 2.5Y or 5Y, value of 3 to 5 moist and 4 to 6 dry, and chroma of 1. It is silt loam, silty clay loam or silty clay. It is medium acid to neutral.

The B2 horizon has hue of 10YR, 2.5Y or 5Y, value of 3 or 4 moist, and 4 or 5 dry, and chroma of 1 or 2. It is silty clay or clay estimated to average between 45 to 60 percent clay. It is neutral to strongly alkaline.

The Cg horizon is silty clay, clay, silty clay loam, loam or clay loam. Mottling in the Cg horizon is lacking in some pedons and in other mottles are few or common, and faint or distinct. It is moderately alkaline or strongly alkaline. Till or soft bedrock is below depths of 40 inches in some pedons.

HEIL SERIES--Z

Competing Series: These are the Ryan and Ranslo series in the same family and the Dimmick, Harriet, Hoven, McKenzie, and Shonkin series. Ryan soils have thicker mollic epipedons and contain free carbonates and lack A2 horizons. Ranslo soils have thicker A1 and A2 horizons. Dimmick soils lack natric horizons. Harriet soils contain free carbonates within depths of 10 inches and are formed in stratified alluvium. Hoven soils have mesic temperatures. McKenzie soils lack mollic epipedons and natric horizons. Shonkin soils lack mollic epipedons and have mesic temperatures.

Geographic Setting The Heil soils are in flat enclosed depressions. Slope gradients are less than 1 percent. The soils formed in clayey calcareous alluvium. Mean annual temperature ranges from 38 to 45° F, and mean annual precipitation from 12 to 16 inches.

Geographically Associated Soils: These are the Amor, Cabba, Dimmick, Harriet, McKenzie, Morton, Reeder, Regent, Sen, Williams and Zahl soils. Dimmick and McKenzie soils are in the same basins adjacent to the Heil soils. Dimmick soils lack excess sodium and are very poorly drained. McKenzie soils lack a natric horizon. Harriet soils are in bottomlands and low terraces. Amor, Cabba, Morton, Reeder, Regent, Sen, Williams and Zahl soils are well drained soils that are on higher positions on the landscape and lack natric horizons.

Drainage and Permeability: Poorly drained. Ponded after heavy rains and melt waters from snow. Permeability is very slow.

Use and Vegetation: Most of these soils are used for rangeland and hay. Vegetation is mixed grasses and sedges: mainly western wheatgrass, prairie cordgrass and common spikesedge.

Distribution and Extent: Western North Dakota, eastern Montana, northwestern South Dakota. The soil is of moderate extent.

Series Established: Bowman County, North Dakota, 1969.

National Cooperative Soil Survey
U.S.A.

Replace Promise series

Established Series
Rev. GBM
6/6/80

LAWTHER SERIES

The Lawther series consists of deep, well drained, slowly permeable soils that formed in calcareous clayey sediments. These soils are on uplands, fans, and terraces and slopes of 0 to 9 percent. Mean annual temperature is 42° F, and mean annual precipitation is 16 inches.

Taxonomic Class: Fine, montmorillonitic Vertic Haploborolls.

Typical Pedon: Lawther silty clay - on a north-facing plane slope of 1 percent in a cultivated field. (Colors are for dry soil unless otherwise stated. Where described, the soil was moist throughout.)

Ap--0 to 5 inches; dark gray (10YR 4/1) silty clay, very dark brown (10YR 2/2) moist; moderate very fine granular structure; very hard, friable, sticky, and very plastic; many fine roots; slight effervescence; moderately alkaline; abrupt smooth boundary. (4 to 12 inches thick)

B2--5 to 20 inches; dark grayish brown (2.5Y 4/2) silty clay, very dark grayish brown (2.5Y 3/2) moist; weak coarse prismatic structure parting to moderate fine angular blocky; very hard, friable, sticky, and very plastic; common fine roots and fine pores; thin films of very dark gray (2.5Y 3/1) moist on faces of peds; slight effervescence; moderately alkaline; gradual wavy boundary. (10 to 20 inches thick)

B3cs--20 to 32 inches; grayish brown (2.5Y 5/2) silty clay, very dark grayish brown (2.5Y 3/2) moist; weak coarse prismatic structure parting to moderate fine angular blocky; extremely hard, firm, sticky, and very plastic; occasional fine roots; few fine pore; thin films of very dark gray (2.5Y 3/1) moist on faces of peds; common fine gypsum crystals; slight effervescence; moderately alkaline; gradual wavy boundary. (0 to 15 inches thick)

C1cacs--32 to 44 inches; olive gray (5Y 5/2) silty clay, very dark grayish brown (2.5Y 3/2) moist; weak very coarse prismatic structure parting to weak fine angular blocky; very hard, firm, sticky, and very plastic; many fine gypsum crystals; many fine accumulations of lime; strong effervescence; moderately alkaline; gradual boundary.

C2cs--44 to 60 inches; pale olive (5Y 6/3) silty clay, olive (5Y 5/3) moist; weak medium angular blocky structure; very hard, friable, sticky, and plastic; few gypsum crystals; strong effervescence; moderately alkaline.

Type Location: Stark County, North Dakota; about 6½ miles north and 1½ miles east of Richardton; 2,640 feet east and 215 feet north of the SW corner of sec. 35, T. 141 N., R. 92 W.

Range in Characteristics: Solum thickness ranges from 20 to more than 40 inches. The mollic epipedon ranges from 7 to more than 20 inches in thickness. The soil typically contains free carbonates to the surface, but some pedons lack carbonates to depths of 30 inches. When the soil is dry, cracks 1/2 to 2 inches wide and several feet long extend downward through the solum. Typically, the series control section averages between 45 to 60 percent clay and 30 to 55 percent silt.

The A horizon has hue of 10YR or 2.5Y, value of 4 or 5 and 2 or 3 moist, and chroma of 1 or 2 dry or moist. It typically is silty clay, but some is clay or silty clay loam. It is neutral to moderately alkaline.

The B horizon has hue of 2.5Y or 5Y, value of 4 or 5 and 2 to 4 moist, and chroma of 1 to 3 dry or moist. It is clay, silty clay, or silty clay loam. It is mildly to strongly alkaline.

The C horizon has hue of 2.5Y or 5Y, value of 4 to 7 and 3 to 6 moist, and chroma of 1 to 3 dry or moist. It is silty clay, clay, or silty clay loam. It is moderately or strongly alkaline. Segregated lime is in the B3 and upper part of the C horizon in some pedon. Some are stratified or laminated.

LAWTHER SERIES--2

Competing Series: This is the only series in this family. Similar series in other families are the Eltsac, Grail, Magnus, Moreau, Nutley, Regent, Savage, and Sinai series. Eltsac soils contain more than 60 percent clay in the series control section. Grail and Savage soils have B2t horizons which average between 35 and 45 percent clay. Magnus soils have an irregular decrease in organic matter content with depth. Moreau and Regent soils have bedded shales at depths of 20 to 40 inches. Nutley and Sinai soils are usually moist.

Geographic Setting: Lawther soils are on level to sloping uplands, fans, and terraces. Slopes are plane or slightly concave. Slope gradients typically range from 0 to 4 percent, but some are as steep as 9 percent. The soil formed in calcareous clayey sediments. The climate is cool, semiarid. Mean annual temperature ranges from 38° to 45° F, and mean annual precipitation from 14 to 17 inches. Most of the precipitation comes in the spring and summer.

Geographically Associated Soils: These are the competing Grail, Moreau, Regent and Savage soils, and the Morton and Sen soils. Grail and Savage soils are on swales and terraces; Moreau, Morton, Regent, and Sen soils are on the nearby upland plains. The Morton and Sen soils contain less than 35 percent clay in the series control section and have soft bedrock at depths of 20 to 40 inches.

Drainage and Permeability: Well drained. Surface runoff is slow or medium. Permeability is slow.

Use and Vegetation: Most areas are cropped to wheat and other small grains. Some is in native grass. Native vegetation includes western wheatgrass, green needlegrass, blue grama, and forbs.

Distribution and Extent: Southwestern North Dakota, northwestern South Dakota, and eastern Montana. The soil is of moderate extent.

Series Established: Bowman County, North Dakota, August 1969.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. GBM
6/6/80

LEFOR SERIES

The Lefor series consists of moderately deep, well drained, moderately permeable soils that formed in soft stratified sandstone. These soils are on uplands and have slopes of 0 to 15 percent. Mean annual temperature is 42° F, and mean annual precipitation is 16 inches.

Taxonomic Class: Fine-loamy, mixed Typic Argiborolls.

Typical Pedon: Lefor fine sandy loam - on a south-facing convex slope of 5 percent under tame grass. (Colors are for dry soil unless otherwise stated. Where described, the soil was dry to 24 inches and moist below.)

Ap--0 to 7 inches; grayish brown (10YR 5/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; moderate medium subangular blocky structure parting to moderate medium and fine granular; hard, friable, slightly sticky; many roots; many fine pores; medium acid (pH 5.6); abrupt smooth boundary. (5 to 9 inches thick)

B1--7 to 15 inches; brown (10YR 5/3) fine sandy loam, dark brown (10YR 3/3) moist; dark grayish brown (10YR 4/2) coatings on faces of prisms; strong coarse prismatic structure parting to weak coarse to fine subangular blocky; hard, friable, slightly sticky; many roots; many fine pores; slightly acid; clear wavy boundary. (0 to 11 inches thick)

B21t--15 to 24 inches; light yellowish brown (2.5Y 6/3) sandy clay loam, olive brown (2.5Y 4/4) moist; brown (10YR 5/3) coatings on faces of prisms; strong very coarse prismatic structure parting to moderate medium angular blocky; very hard, friable, slightly sticky and slightly plastic; common roots; many fine pores; neutral; gradual wavy boundary.

B22t--24 to 30 inches; light yellowish brown (2.5Y 6/4) sandy clay loam, olive brown (2.5Y 4/4) moist; thin grayish brown (2.5Y 5/2) coatings on faces of prisms; strong very coarse prismatic structure parting to moderate medium angular blocky; very hard, friable, slightly sticky and slightly plastic; few fine roots; common fine pores; mildly alkaline; clear wavy boundary. (Combined thickness of B2t horizons is 8 to 22 inches thick.)

B3ca--30 to 36 inches; pale yellow (2.5Y 7/4) fine sandy loam, light olive brown (2.5Y 5/4) moist; strong very coarse prismatic structure parting to moderate medium angular blocky; hard, friable, slightly sticky and slightly plastic; few roots; common fine and medium pores; few fine soft masses of carbonates; strong effervescence; moderately alkaline; clear wavy boundary. (0 to 9 inches thick)

Cr--36 to 60 inches; pale yellow and white (2.5Y 7/4 and 8/4 and 5Y 8/2) sedimentary beds of soft fine grained sandstone, light yellowish brown and light gray (2.5Y 6/4 and 5Y 7/2) moist; sandstone breaks apart to laminar or platelike structure; gypsum crystals in some layers; slight effervescence in some layers and no effervescence in others; moderately alkaline.

Type Location: Stark County, North Dakota; about 12 1/2 miles south and 8 miles east of Dickinson; 290 feet east and 2,555 feet south of the northwest corner of sec. 13, T. 137 N., R. 94 W.

Range in Characteristics: Solum thickness ranges from 20 to 40 inches. It commonly is the same as the depth to soft sandstone.

The A1 or Ap horizon has hue of 10YR of 2.5Y, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3 dry or moist. It is loam, sandy loam, or fine sandy loam.

The B1 horizon has hue of 10YR or 2.5Y, value of 4 to 6 and 2 to 5 moist, and chroma of 2 to 4 dry or moist. It is fine sandy loam, loam, or sandy loam. It has weak to strong prismatic structure which parts to weak or moderate blocky structure.

The B2t horizon has hue of 10YR or 2.5Y, value of 5 to 7 and 4 to 6 moist, and chroma of 2 to 4 dry or moist. It is sandy clay loam or loam and averages between 18 and 27 percent clay, 15 and

LEFOR SERIES--2

30 percent silt and 25 and 65 percent fine sand and coarser. It has moderate or strong prismatic structure which parts to weak to strong blocky structure. The peds have thin to thick clay films and have stains of organic matter.

The B3ca horizon has hue of 2.5Y or 10YR, value of 5 to 8 and 4 to 6 moist, and chroma of 2 to 4. It is fine sandy loam, sandy loam, loam, or sandy clay loam and contains less than 15 percent $CaCO_3$. Where present, the Cca horizon is similar to the B3ca horizon, except it has weaker structure.

The Cr horizon is soft fine-grained sandstone.

Competing Series: These are the Dooley, Empedrado, Fairfield, Farnuf, Felor, Greenway, Livona, Martinsdale, Moen, Reeder, Trag, Vida, Watrous, Williams, and Yegen series in the same family and the Farland, Flaxton, Morton, Savage, and Vebar series. Dooley, Empedrado, Fairfield, Farnuf, Felor, Greenway, Livona, Martinsdale, Trag, Vida, Williams, and Yegan series all lack soft sandstone bedrock at depths of 20 to 40 inches. Moen and Watrous soils have lithic contact at a depth of 20 to 40 inches. Reeder soils typically contain less than 45 percent fine sand and coarser, and contain more clay. Farland and Morton soils have fine-silty textures. Flaxton soils have mollic epipedons more than 16 inches thick. Savage soils have fine textures. Vebar soils lack argillic horizons and have coarse-loamy textures.

Geographic Setting: Lefor soils are on nearly level to rolling uplands. Slope gradients range from 0 to 15 percent. The soils formed in soft stratified sandstone from the Golden Valley formation. The climate is semiarid. Mean annual temperature ranges from 38° to 45° F, and mean annual precipitation from 14 to 17 inches. Most of the precipitation comes in the spring and summer.

Geographically Associated Soils: These are the competing Morton, Reeder, and Vebar soils, and Cabba, Cohagen, Flasher, Parshall, and Tally soils. Morton, Reeder, and Vebar soils are on nearby uplands. Cabba, Cohagen, and Flasher soils are on nearby steep hills and have soft bedrock within depths of 20 inches. Parshall and Tally soils are in nearby swales or on terraces and lack argillic horizons. In addition, they have coarse-loamy textures, and Parshall soils have mollic epipedons more than 16 inches thick.

Drainage and Permeability: Well drained. Surface runoff is slow or medium. Permeability is moderate.

Use and Vegetation: Soils are cropped to small grains. Some is used for hay and pasture. Native vegetation was needleandthread, prairie sandreed, western wheatgrass, blue gram, and a variety of forbs.

Distribution and Extent: Western North Dakota and northwestern South Dakota. The soil is of moderate extent.

Series Established: Stark County, North Dakota, 1965.

Remarks: The Lefor soils have a low cation exchange capacity.

Additional Data: S58NDak-45-21 Soil Survey Laboratory and S58NDak-4522 pages 153-153, Soil Survey Investigations Report No. 2, North Dakota.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. CAM/SHB
11/76

LIHEN SERIES

The Lihen series consists of deep, well drained soils that formed in sandy alluvium and eolian deposits. Lihen soils are on terraces and uplands and are nearly level to strongly sloping. The mean annual precipitation is about 13 inches, and the mean annual air temperature is about 43°F.

Taxonomic Class: Sandy, mixed Entic Haploborolls.

Typical Pedon: Lihen loamy fine sand, grassland. (Colors are for dry soil unless otherwise noted.)

A11--0 to 3 inches; dark grayish brown (10YR 4/2) loamy fine sand, very dark brown (10YR 2/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine roots and pores; neutral (pH 7.0); clear wavy boundary.

A12--3 to 19 inches; dark grayish brown (10YR 4/2) loamy fine sand, very dark brown (10YR 2/2) moist; weak coarse prismatic structure parting to single grained; soft, very friable, nonsticky and nonplastic; many fine roots; neutral (pH 7.2); gradual smooth boundary. (The A horizon is 10 to 30 inches thick.)

AC--19 to 30 inches; dark grayish brown (10YR 4/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; single grained; loose; common fine roots; slightly effervescent; mildly alkaline (pH 7.6); gradual smooth boundary.

C1ca--32 to 45 inches; light gray (10YR 7/2) loamy sand, grayish brown (10YR 5/2) moist; single grained; loose; few fine roots; few lime nodules and coatings of lime on sand grains; violently effervescent; moderately alkaline (pH 8.0); gradual smooth boundary.

C2ca--45 to 60 inches; light brownish gray (2.5Y 6/2) sandy loam, dark grayish brown (2.5Y 4/2) moist; massive; soft, very friable, nonsticky and nonplastic; violently effervescent; moderately alkaline (pH 8.0).

Type Location: Roosevelt County, Montana; section 23, T.29N., R.53E.

Range in Characteristics: The mean annual soil temperature is 41° to 46°F. Hue is 10YR or 2.5Y. Some pedons contain up to 10 percent pebbles. The soils are mainly 10 to 36 inches to calcareous material, but some pedons are calcareous throughout.

The A horizon has value of 4 or 5 dry, 2 or 3 moist, and chroma of 2 or 3. It is loamy fine sand, fine sandy loam, loamy sand, or sand. This horizon is neutral or mildly alkaline.

Some pedons lack a Cca horizon but are calcareous throughout.

The C horizon has value of 4 through 7 dry, 3 through 5 moist and chroma of 2 through 4. It is loamy fine sand, fine sand, or sand. Some pedons contain thin lenses of sandy loam or fine sandy loam. This horizon is mildly or moderately alkaline. The $CaCO_3$ equivalent is 2 to 14 percent. Some pedons lack the underlying sandy loam materials and are sandy to depths greater than 60 inches.

Competing Series: These are the Telfer series in the same family, and the Blanchard, Flasher, and Seroco series. Blanchard, Flasher and Seroco soils lack mollic epipedons. Also, Flasher soils have soft sandstone at depths of less than 20 inches. Telfer soils lack lime in the profile.

Geographic Setting: Lihen soils are nearly level to hilly and are on stream terraces and uplands, at elevations of 2,000 to 4,000 feet. They formed in wind or water deposited sandy material. Climate is cool semiarid with a mean annual temperature of 41° to 46°F. The average annual precipitation is 10 to 16 inches, most of which falls during the spring and early summer. The 32°F growing season is 105 to 130 days.

Geographically Associated Soils: These are the Parshall soils and the competing Blanchard and Flasher soils. Parshall soils have sandy loam and coarse loam textures between depths of 10 and 40 inches.

Drainage and Permeability: Well drained; slow runoff; rapid permeability.

Use and Vegetation: Lihen soils are used for dryland cropland and for range. The main native vegetation is prairie sandreed, little bluestem, needleandthread, Indian ricegrass, prairie junegrass, western wheatgrass, and some forbs and shrubs.

Distribution and Extent: Eastern and northern Montana, North Dakota, and South Dakota. It is moderately extensive.

Series Established: Central Montana Reconnaissance Survey, 1946.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. GBM
9/14/79

MANNING SERIES

The Manning series consists of somewhat excessively drained soils moderately deep to sand or sand and gravel. Permeability is moderately rapid in the solum, and very rapid in the substratum. These soils formed in loamy sediments overlying sand and gravel on stream and outwash terraces. They have slopes of 0 to 15 percent. Mean annual temperature is 42° F, and mean annual precipitation is 16 inches.

Taxonomic Class: Coarse-loamy over sandy or sandy-skeletal, mixed Typic Haploborolls.

Typical Pedon: Manning fine sandy loam - on a south-facing plane slope of 1 percent under grass. (Colors are for dry soil unless otherwise stated. Where described, the soil was moist throughout.)

Ap--0 to 5 inches; dark grayish brown (10YR 4/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky structure parting to moderate medium granular; slightly hard, very friable, slightly sticky, slightly plastic; many fine roots; many fine pores; few pebbles; neutral; abrupt smooth boundary. (4 to 8 inches thick)

B21--5 to 12 inches; brown (10YR 5/3) fine sandy loam, dark brown (10YR 3/3) moist; moderate coarse and medium prismatic structure parting to moderate medium subangular blocky; hard, very friable, slightly sticky, slightly plastic; common fine roots; many fine pores; few thin clay films on faces of peds; few pebbles; neutral; gradual wavy boundary.

B22--12 to 18 inches; brown (10YR 5/3) fine sandy loam, brown (10YR 4/3) moist; moderate coarse and medium prismatic structure parting to weak medium subangular blocky; slightly hard, very friable, slightly sticky, slightly plastic; common fine roots; common fine pores; few thin clay films on faces of prisms; few pebbles and cobbles; neutral; clear wavy boundary. (Combined B2 horizons 8 to 24 inches thick.)

C1ca--18 to 23 inches; light brownish gray (2.5Y 6/2) fine sandy loam, dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure parting to weak medium subangular blocky; slightly hard, very friable, slightly sticky, nonplastic; few roots; common fine pores; about 10 percent gravel; violent effervescence; common fine soft masses of lime; moderately alkaline; clear wavy boundary. (3 to 10 inches thick)

IIC--23 to 40 inches; light yellowish brown (2.5Y 6/4) sand and gravel, olive brown (2.5Y 4/3) moist; single grain; loose; few fine roots; about 25 percent gravel coarser than 3/4 inch; few cobbles; some pebbles and cobbles have thin accumulations of lime on undersides; strong effervescence in upper part; slight effervescence in lower part; moderately alkaline; clear wavy boundary. (9 to 36 inches thick)

IIC3--40 to 60 inches; light brownish gray (2.5Y 6/2) sand and strata of fine gravel, dark grayish brown (2.5Y 4/2) moist; single grain; loose; about 10 percent gravel; slight effervescence; moderately alkaline.

Type Location: Stark County, North Dakota; about 4 1/2 miles west and 1 mile south of Dickinson; 600 feet east and 100 feet south of the NW corner of the NE quarter of sec. 15, T. 139 N., R. 97 W.

Range in Characteristics: Solum thickness and depth to free carbonates typically ranges from 13 to 28 inches. The depth to sand and gravel typically is 20 to 34 inches and ranges from 16 to 40 inches. The soil material between depths of 10 inches and the sand and gravel averages between 35 and 50 percent fine sand and coarser and 8 and 18 percent clay. The mollic epipedon ranges from 7 to 16 inches in thickness.

The A horizon has hue of 10YR, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3 dry or moist. It typically is sandy loam or fine sandy loam, but some is coarse loam. It contains as much as 3 percent by volume of coarse fragments.

The B2 horizon typically has hue of 10YR, but hue of 2.5Y is in the lower part in some pedons. It has value of 4 through 6 and 3 or 4 moist, and chroma of 2 through 4 dry or moist. It is fine sandy loam, sandy loam, or coarse loam. It contains from 1 to 10 percent by volume of coarse fragments. Some pedons have B3 horizon.

MANNING SERIES--2

The Cca horizon has hue of 10YR or 2.5Y, value of 5 through 7 and 4 through 6 moist, and chroma of 2 or 3 dry or moist. It is sandy loam, fine sandy loam, coarse sandy loam, or coarse loam. It contains 2 to 15 percent coarse fragments and 5 to 20 percent calcium carbonate.

The IIC horizon contains strata of sand and gravel. The gravel content typically averages between 35 and 75 percent; over 25 percent by volume is over 3/4 inch in diameter.

Competing Series: There are no other series in the same family. Series in closely related families are the Arvilla, Bowdle, Chanta, Chinook, Grantsdale, Lehr, McIlwaine, Parshall, Stady, Tally, and Vebar soils. Arvilla soils are moist for a longer period and have A1 horizons with chroma of 1. Bowdle, Chanta, Grantsdale, Lehr, and Stady soils are fine-loamy over sandy or sandy-skeletal. In addition, Bowdle soils have mollic epipedons more than 16 inches thick and Chanta soils are dry for a longer period. Chinook soils lack sand and gravel IIC horizons. McIlwaine soils have mollic epipedons more than 16 inches thick. Parshall soils have mollic epipedons more than 16 inches thick and lack sand and gravel IIC horizons within depths of 40 inches. Tally soils lack sand and gravel IIC horizons within depths of 40 inches. Vebar soils have soft sandstone bedrock within depths of 20 to 40 inches.

Geographic Setting: Manning soils are on smooth and plane nearly level and gently sloping stream and outwash terraces. Slope gradients typically are less than 5 percent but some are as steep as 6 to 15 percent on terrace edges and some outwash areas. These soils formed in 16 to 40 inches of loamy sediments over sand and gravel. The climate is semiarid. Mean annual temperatures range from 38 to 45° F, and mean annual precipitation from 12 to 16 inches. Most of the moisture falls in the spring and summer.

Geographically Associated Soils: These are the competing Bowdle, Lehr, Parshall, Stady, Tally, and Vebar soils, the Farland, Straw, Velva, and Wabek soils. All of these soils except the Vebar soils are on nearby terraces, commonly at different levels. Vebar soils are on nearby uplands. Farland soils are fine-silty. Straw soils have irregular decreases in organic matter with depth and thick mollic epipedons. Velva soils are on nearby high floodplains and have an irregular decrease in organic matter with depths. Wabek soils are on steep terrace edges and ridges and are sandy-skeletal.

Drainage and Permeability: Somewhat excessively drained. Surface runoff is slow. Permeability is moderately rapid through the solum and very rapid in the IIC horizon.

Use and Vegetation: Soils are cropped to small grains, corn, and tame grass for hay and pasture. Native vegetation is needleandthread, prairie sandreed, prairie junegrass, sun sedge, threadleaf sedge, and a wide variety of forbs.

Distribution and Extent: Southwestern North Dakota, northwestern South Dakota, and eastern Montana. The soil is of moderate extent.

Series Established: Stark County, North Dakota, 1963.

Remarks: The typifying pedon contains more sand in the 40- to 60-inch layer than is common for the Manning series.

Additional Data: S58NDak-45-1 Soil Survey Investigations Report No. 2, pages 162 and 163 and SU72NDak-6-1 - North Dakota Agricultural Experiment Station.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. GBM
8/8/80

MOREAU SERIES

The Moreau series consists of moderately deep, well drained, slowly permeable soils that formed in soft calcareous alkaline shales. These soils are on sedimentary upland plains and have slopes ranging from 0 to 25 percent. Mean annual temperature is 42° F, and mean annual precipitation is 15 inches.

Taxonomic Class: Fine, montmorillonitic Typic Haploborolls.

Typical Pedon: Moreau silty clay on an east northeast-facing convex slope of 2 percent under cropland. (Colors are for dry soils unless otherwise stated. When described, the soil was moist throughout.)

Ap--0 to 6 inches; grayish brown (2.5Y 5/2) silty clay, very dark grayish brown (2.5Y 3/2) moist; weak medium subangular blocky structure parting to moderate very fine granular; very hard, friable, sticky and plastic; common fine roots; many fine pores; slight effervescence; moderately alkaline; abrupt smooth boundary. (4 to 10 inches thick)

B21--6 to 12 inches; grayish brown (2.5Y 5/2) silty clay, dark grayish brown (2.5Y 5/2) moist; weak coarse prismatic structure parting to strong fine subangular blocky; very hard, firm, sticky and plastic; few roots; common fine pores; strong effervescence (8 percent $CaCO_3$ equivalent); moderately alkaline; gradual wavy boundary.

B22--12 to 21 inches; light yellowish brown (2.5Y 6/4) silty clay, olive brown (2.5Y 4/4) moist; weak coarse prismatic structure parting to moderate medium and fine subangular blocky; very hard, firm, sticky and plastic; few fine roots; common fine pores; few soft yellowish brown (10YR 5/6) moist iron stains 1/4 to 4 inches in diameter; few fine gypsum crystals; strong effervescence, (10 percent $CaCO_3$ equivalent); moderately alkaline; clear wavy boundary. (Combined B2 horizon is 5 to 20 inches thick.)

C--21 to 29 inches; light olive gray (5Y 6/2) silty clay, olive gray (5Y 4/2) moist; weak coarse subangular blocky structure; very hard, firm, sticky and plastic; few fine roots; few fine pores; few gypsum crystals; strong effervescence (14 percent $CaCO_3$ equivalent); laminations inherited from soft platy shale throughout; moderately alkaline; clear wavy boundary. (4 to 12 inches thick)

Cr--29 to 60 inches; light olive gray (5Y 6/2) soft platy shale; common nests of gypsum crystals; very hard and brittle when dry; strong effervescence; moderately alkaline.

Type Location: Slope County, North Dakota; about 9 miles east and 9 1/2 miles south of Amidon; 130 feet east and 2,615 feet south of the northwest corner of sec. 9, T. 133 N., R. 99 W.

Range in Characteristics: Solum thickness typically is 20 to 24 inches and ranges from 13 to 38 inches. The soil typically contains 2 to 15 percent calcium carbonate. The depth to soft shale commonly is 20 to 30 inches and ranges from 20 to 40 inches.

The A horizon has hue of 2.5Y or 10YR, value of 4 or 5 and 2 or 3 moist. It typically is silty clay but is clay, silty clay loam, or clay loam in some pedons.

The B2 horizon has hue of 10YR or 2.5Y, and rarely 5Y; value of 5 or 6 and 3 to 5 moist; and chroma of 2 to 4. It is silty clay, clay, or silty clay loam. It typically averages between 45 and 55 percent clay but ranges from 35 to 60 percent. It has weak or moderate grades of prismatic structure parting to weak to strong subangular or angular blocky.

Some pedons have a B3ca or Cca horizon.

The C horizon has hue of 2.5Y or 5Y, value of 5 to 7 and 4 to 6 moist, and chroma of 2 to 4. It is clay or silty clay, and rarely silty clay loam; and contains 35 to 60 percent clay. It contains few to many gypsum crystals and lime diffused or in soft masses. It has an EC greater than 2 mmhos per cm and ESP of 4 to 12.

MOREAU SERIES--2

The Cr material has hue of 5Y or 2.5Y, value of 5 to 7, and chroma of 2 to 4. It is laminated in some pedons and massive in others. It contains crystals or lenses of gypsum and is moderately or strongly alkaline.

Competing Series: These are the Winifred series in the same family and the Barkof, Dimyaw, Lawther, Linwell (tentative), Regent, Savage, and Wayden series. Winifred series have distinct horizons of segregated lime and are noncalcareous in the upper 8 to 12 inches. Barkof soils have cracks extending to 20 to 30 inches below the surface when dry. Dimyaw, Lawther, Linwell (t), and Savage soils do not have a paralithic contact within a depth of 40 inches. Regent soils have an argillic horizon. Wayden soils have a paralithic contact within a depth of 20 inches.

Geographical Setting: Moreau soils are on very gently undulating and rolling sedimentary upland plains. Slope gradients commonly are 2 to 5 percent, but range from 0 to 25 percent. The soils formed in soft calcareous, alkaline shales. The climate is cool, semiarid. The mean annual temperature ranges from 38° to 45° F, and the mean annual precipitation ranges from 14 to 17 inches. Most of the precipitation comes in the spring and summer.

Geographically Associated Soils: These are the competing Dimyaw, Lawther, Regent, Savage, and Wayden soils and the Cabba, Daglum, Grail, Morton, Sen, and Rhoades soils. Dimyaw and Wayden soils are on crests of hills and steep slopes. Lawther and Savage soils are on level concave swales and terraces. Regent soils are on similar landscapes with Moreau soils. Cabba, Morton, and Sen soils are on nearby uplands. Cabba soils have bedded siltstone at shallow depths and are on steep slopes. Morton and Sen soils are fine-silty. Daglum and Rhoades soils have a natric horizon. They are on nearby uplands and terraces, and are in complex with Moreau soils in some areas. Grail soils are in nearby concave swales. They have a mollic epipedon more than 16 inches thick.

Drainage and Permeability: Well drained. Runoff is medium or rapid. Permeability is slow.

Use and Vegetation: Soils are cropped to small grains, and used for range and pasture. Native vegetation is western wheatgrass, blue grama, green needlegrass, and a variety of forbs.

Distribution and Extent: Southwestern North Dakota, northwestern South dakota, and eastern Montana. The soil is extensive.

Series Established: Wibaux County, Montana, 1956.

Additional Data: S54NDak-21-2 in Soil Survey Investigation Report No. 2, pp. 194-195.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. GBM
6/6/80

MORTON SERIES

The Morton series consists of moderately deep, well drained, moderately permeable soils that formed in material weathered from soft calcareous silty shales, siltstones, and fine grained sandstones. These soils are on uplands and have slopes of 0 to 10 percent. Mean annual temperature is 42° F, and mean annual precipitation is 15 inches.

Taxonomic Class: Fine-silty, mixed Typic Argiborolls.

Typical Pedon: Morton silt loam - native grassland. (Colors are for dry soil unless otherwise stated.)

A1--0 to 5 inches; dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate granular structure grading to prismatic in the lower part; friable; many roots; many fine pores; neutral; clear smooth boundary. (3 to 12 inches thick)

B21t--5 to 11 inches; dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium prismatic structure parting to moderate medium angular blocky; friable; many roots; many fine pores; thin continuous clay films on peds; neutral; gradual smooth boundary.

B22t--11 to 18 inches; brown (10YR 5/3) silty clay loam, dark brown (10YR 4/3) moist; moderate medium prismatic structure parting to medium and fine angular blocky; friable; common roots; common medium pores; thin clay films of dark grayish brown (10YR 4/2) on peds; mildly alkaline; clear irregular boundary. (Combined thickness of B2 horizons is 6 to 22 inches thick.)

B3ca--18 to 26 inches; light yellowish brown (2.5Y 6/3) silty clay loam, light olive brown (2.5Y 5/3) moist; moderate coarse and medium prismatic structure parting to weak coarse and medium subanglar blocky; friable; few roots; common fine pores; strong effervescence; moderately alkaline; gradual wavy boundary. (0 to 10 inches thick)

Cca--26 to 35 inches; light olive gray (5Y 6/2) silty clay loam, olive gray (5Y 5/2) moist; weak prismatic structure; few roots; few fine pores; violent effervescence; moderately alkaline; gradual boundary. (2 to 10 inches thick)

Cr--35 to 60 inches; platy soft siltstone and soft shale.

Type Location: Hettinger County, North Dakota; 0.15 mile east of NW corner sec. 21, T. 136 N., R. 95 W.

Range in Characteristics: The depth to carbonates ranges from 11 to 30 inches, and the depth to soft shale or siltstone ranges from 20 to 40 inches.

The A horizon is silt loam, loam, silty clay loam, or clay loam. Glacial stones are common in the surface layer in the eastern and northern part of the geographic range of the soil and a stony phase is recognized. It is slightly acid or neutral.

The B2t horizon has hue of 7.5YR, 10YR, or 2.5Y, value of 4 to 6, and chroma of 2 to 4. It is loam, silt loam, or silty clay loam and commonly 20 to 26 percent clay, but range of 18 to 35 percent is permitted. It typically has moderate or strong coarse to fine prismatic and angular or subangular blocky structure. Peds in the B2t horizon have thin continuous or patchy clay films. It is neutral or mildly alkaline.

The B3ca horizon and the Cca horizon contain both diffuse and segregated lime; the calcium carbonate equivalent is 10 to 20 percent. The Cca horizon has hue of 2.5Y or 5Y, value of 5 to 7, 4 or 5 moist, and chroma of 2 to 4. The platiness of the original rock structure is evident in some of the weathered soft shale and siltstone layers; others are massive. It is mildly or moderately alkaline.

MORTON SERIES--2

Competing Series: These are the Farland, Jekley, and Xavier soils in the same family and the Belfield, Grail, Lefor, Regent, Savage, Sen, and Williams series. Farland soils formed in alluvium and lack soft bedrock at depths of less than 40 inches. Jekley soils have a lithic contact at a depth of 20 to 40 inches. Xavier soils have thinner B2t horizons and lack soft bedrock within depths of 40 inches. Belfield soils have thin albic horizons and natric horizons and are fine. Grail soils have mollic epipedon more than 20 inches thick and are fine. Lefor soils are fine-loamy and lack soft bedrock within depths of 40 inches. Regent and Savage soils are fine. In addition, Savage soils lack soft bedrock within depths fo 40 inches. Sen soils lack argillic horizons, have weather structure, contain less clay and more silt, and carbonates are at shallower depths. Williams soils are fine loamy and are formed in glacial till.

Geographic Setting: Morton soils are on nearly level, undulating and rolling plains. Slope gradient is commonly 0 to 6 percent, but in a few places it is more than 10 percent. The soils formed in material weathered from soft calcareous silty shales, siltstones, and fine grained sandstones. Some areas have a thin glacial till mantle. Mean annual temperature is 38° to 45° F, and mean annual precipitation is 12 to 17 inches. Most of the precipitation comes in the spring and summer.

Geographically Associated Soils: These are the Flasher and Werner soils on the steeper hilltops and ridges and the Arnegard or the competing Grail soils in the concave swales and flats below the Morton soils, and the competing Farland and Savage soils mainly in the stream valleys at lower elevations. The competing Belfield and Regent soils and the Rhoades and Vebar soils are on the same plain as the Morton soils. Arnegard soils are deep and have a mollic epipedon greater than 16 inches thick. Flasher soils are less than 20 inches deep to a soft bedrock and are sandy. Rhoades soils have natric horizons that have strong prismatic or columnar structure, and they formed in strongly alkaline shales. Vebar soils are coarse-loamy and underlain by soft sandstone. Werner soils are less than 20 inches deep to a paralithic contact. In a few localities where thick glacial till is intermixed with silty residual material, the competing Williams soils are associated with Morton soils.

Drainage and Permeability: Well drained. Runoff is medium or rapid. Permeability is moderate.

Use and Vegetation: Cultivated areas are used for growing small grains, flax, corn, hay, and pasture. Native vegetation is mid and short prairie grasses as western wheatgrass, green needlegrass, and blue grama.

Distribution and Extent: Southwestern North Dakota, northwestern South Dakota, and eastern Montana. The soil is extensive.

Series Established: Morton area, North Dakota, 1907.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. GBM
11/16/78

PARSHALL SERIES

The Parshall series consists of deep, well drained, moderately rapid permeable soils formed in alluvium. These soils are on terraces, outwash plains and upland swales and have slopes of 0 to 15 percent. Mean annual temperature is 42° F, and mean annual precipitation is 16 inches.

Taxonomic Class: Coarse-loamy, mixed Pachic Haploborolls.

Typical Pedon: Parshall fine sandy loam - cultivated. (Colors are for dry soil unless otherwise stated.)

A1--0 to 14 inches; dark grayish brown (10YR 4/2) fine sandy loam, very dark brown (10YR 2/2) moist; weak coarse subangular blocky structure in the upper part, weak coarse prismatic structure in lower part; very friable; many roots; neutral; gradual smooth boundary. (8 to 22 inches thick)

B2--14 to 31 inches; dark grayish brown (10YR 4/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak coarse prismatic structure parting to weak coarse and medium subangular blocky; very friable; common roots; few pores; dark stains and thin patchy films on vertical ped faces; sand grains coated; neutral; gradual wavy boundary. (9 to 25 inches thick)

B3ca--31 to 37 inches; grayish brown (10YR 5/2) fine sandy loam, dark grayish brown (10YR 4/2) moist; weak coarse prismatic structure; very friable; few roots; few fine threads of lime in small root channels; violent effervescence; mildly alkaline; gradual wavy boundary. (0 to 8 inches thick)

Cca--37 to 49 inches; light brownish gray (10YR 6/2) fine sandy loam, dark grayish brown (10YR 4/2) moist; weak coarse subangular blocky structure; very friable; common fine threads of segregated lime, violent effervescence; moderately alkaline; clear wavy boundary. (0 to 16 inches thick)

Ab--49 to 62 inches; grayish brown (10YR 5/2) sandy loam, very dark grayish brown (10YR 3/2) moist; weak very coarse subangular blocky structure; very friable; slight effervescence; moderately alkaline.

Type Location: Morton County, North Dakota; Northern Great Plains Field Station at Mandan; 1,560 feet east and 1,910 feet south of NW corner sec. 33, T. 139 N., R. 81 W.

Range in Characteristics: The depth to carbonates ranges from 24 to 60 inches. The horizon of carbonate accumulation is too thin or too low in carbonates for a calcic horizon.

The A1 horizon has hue of 10YR, value of 2 or 3, moist and chroma of 2. The A horizon is most commonly fine sandy loam, but some is loam or sandy loam.

The B2 horizon has 10YR hue, value of 2 or 3 moist, and chroma of 2 through 4.

The C horizon typically is fine sandy loam but includes sandy loam, or loamy fine sand or loamy sand. One or more buried A horizons are beneath the solum in some pedons. These are most commonly in areas of the soil formed in glacial outwash or wind modified material. A few small pebbles are throughout some pedons. Some pedons have gravelly or silty substrata below 40 inches.

Competing Series: These are the Breece, Hedoes, and Ruso soils in the same family and the Blendon, Embden, Lihen, Manning, Tally, Vebar, and Vetal soils. Breece soils lack free carbonates to depths of 40 inches or more and contain more coarser sand. Hedoes soils are less than 24 inches deep to an accumulation of $CaCO_3$. Russ soils have stratified sand and gravel above depths of 40 inches. Blendon and Vetal soils have mesic temperatures. Embden soils have Ap horizons that have chroma of 1 when moist. Lihen soils are sandy. Manning soils have stronger structure in the B2 horizon and sand and gravel at depths of 15 to 30 inches. Tally soils have mollic epipedons less than 16 inches thick. Vebar soils have mollic epipedons less than 16 inches thick, and the substratum is soft sandstone.

PARSHALL SERIES--2

Geographic Setting: Parshall soils are on nearly level high terraces along river valleys, and also on outwash plains and in swales in uplands. Slope gradients are commonly less than 4 percent but ranges from 0 to 15 percent. The soils formed in alluvium. Mean annual temperature is 38° F, to 45° F, and mean annual precipitation is 12 to 16 inches.

Geographically Associated Soils: Soils on nearby terraces of different elevations are the silty Farland soils, the infrequently flooded Straw soils on lower terraces and the Lehr soils on loamy over gravelly outwash. Soils formed in residuum on plains are the Cabba, Flasher, and Morton soils and the competing Vebar soils. Williams soils are on nearby glaciated plains. The competing Manning and Tally soils are common associates as are the competing Lihen soils in a few places.

Drainage and Permeability: Well drained. Runoff is slow. Permeability is moderately rapid.

Use and Vegetation: Most areas cropped to small grains, flax, tame grass, and alfalfa. Native vegetation was medium and short prairie grasses as green needlegrass, needleandthread, bluegrama, upland sedges and some legumes.

Distribution and Extent: Western North Dakota, northwestern South Dakota, and eastern Montana. The soil is moderately extensive.

Series Established: Northern Great Plains Field Station, Mandan, Morton County, North Dakota, 1960.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. GBM
12/8/78

REGENT SERIES

The Regent series consists of moderately deep, well drained, slowly permeable soils formed in residuum weathered from alkaline soft shales. These soils are on upland plains and have slopes of 2 to 25 percent. Mean annual temperature is 42° F, and mean annual precipitations is 16 inches.

Taxonomic Class: Fine, montmorillonitic Typic Argiborolls.

Typical Pedon: Regent silty clay loam - cultivated. (Colors are for dry soil unless otherwise stated.)

A1--0 to 10 inches; dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky and moderate fine granular structure; firm, plastic; common fine roots; common fine pores; neutral; clear smooth boundary. (5 to 10 inches thick)

B21t--10 to 18 inches; grayish brown (2.5Y 5/2) silty clay, dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure separating to strong fine angular blocky; firm, plastic; few roots; common fine pores; dark grayish brown (10YR 4/2) clay films on faces of peds; mildly alkaline; clear wavy boundary. (3 to 10 inches thick)

B22t--18 to 26 inches; light brownish gray (2.5Y 6/2) silty clay, olive brown (2.5Y 4/3) moist; weak coarse prismatic structure separating to moderate medium subangular blocky; firm, plastic; few roots; common very fine pores; thin clay films on faces of peds; few faint white masses of lime; mildly alkaline; gradual wavy boundary. (4 to 12 inches thick)

B3ca--26 to 39 inches; pale olive (5Y 6/3) silty clay loam, olive (5Y 5/3) moist; weak coarse prismatic structure separating to moderate medium subangular blocky; firm, plastic; few fine pores; common fine threads and few nodules of lime; strongly effervescent; moderately alkaline; clear wavy boundary. (0 to 22 inches thick)

Cr--39 to 62 inches; pale olive (5Y 6/3) soft platy shale; moderately alkaline.

Type Location: Stark County, North Dakota; northwest corner sec. 3, T. 139 N., R. 97 W.

Range in Characteristics: Depth to soft shale bedrock typically is 30 to 40 inches but ranges from 20 to 40 inches. The mollic epipedon ranges from 7 to 16 inches in thickness.

The A horizon has hue of 10YR or 2.5Y, value of 4 or 5, 2 or 3 moist, and chroma of 2 or 3 dry or moist. It is clay loam, silty clay loam or silty clay. Reaction is slightly acid or neutral.

The B2t horizon has hue of 10YR, 2.5Y or 5Y, value of 4 through 6, 2 through 4 moist, and chroma of 2 or 3 dry or moist. It is silty clay loam or silty clay and typically averaging between 35 and 50 percent clay. Reaction is mildly alkaline to strongly alkaline. Most pedons have lime accumulation in either the B3ca or Cca horizon. These horizons commonly contain less than 15 percent $CaCO_3$ equivalent.

The Cr horizon is soft alkaline shale which is stratified with silty layers in some pedons.

Competing Series: These are the Absarokee, Bearpaw, Danvers, Delsan, Mondamin, Savage and Work series in the same family and the Darret, Grail, Moreau, Morton, and Winifred series. The Absarokee soils have hard sandstone bedrock at depths of 20 to 40 inches. Bearpaw, Danvers, Delson, Mondamin, Savage and Work soils lack bedrock within depths of 40 inches. In addition, Davers, Delson and Work series formed in alluvium; Bearpaw formed in glacial till; Mondamin soils formed in glaciolacustrine sediments; and Savage soils formed in alluvium and loess. Darret soils have redder hue and mixed mineralogy. Grail soils have mollic epipedons over 16 inches thick and have formed in alluvium. Moreau and Winifred soils lack argillic horizons. Morton soils are fine-silty.

Geographic Setting: Regent soils are on long and plane or slightly convex slopes of upland plains. The slope gradients commonly are 2 to 4 percent but range to 25 percent. The soils formed in residuum weathered from alkaline soft shales. Mean annual temperature ranges from 38 to 45° F. and mean annual precipitation from 12 to 16 inches.

REGENT SERIES--2

Geographically Associated Soils: These are mainly the competing Grail, Moreau and Morton soils. Grail soils are in concave swales and fans at lower elevations and Moreau soils are on the steeper convex slopes. Morton soils are in nearby landscapes. Beckton, Rhoades and Savage soils are adjacent to Regent soils in some localities. Both Beckton and Rhoades soils have B2t horizons having strong columnar structure and have strongly alkaline subsoils and substrata. In addition, Rhoades soils have thin A2 horizons. Both are commonly on slightly lower, less sloping areas than Regent soils. Savage soils are on nearly level terraces in nearby stream valleys.

Drainage and Permeability: Well drained. Runoff is slow or moderately rapid, depending upon the slope gradient. Permeability is slow.

Use and Vegetation: Cultivated areas are used for growing small grains, flax, hay and pasture. Native vegetation is mid and short grasses such as western wheatgrass, green needlegrass, blue grama, buffalograss and some forbs and upland sedges.

Distribution and Extent: Southwestern North Dakota, eastern Montana, northwestern South Dakota. The soil is extensive.

Series Established: Wibaux County, Montana, 1944

Additional Data: S54ND-45-3, S54ND-21-1, S58NE-13-1, S58ND-45-4, S58ND-45-9 and S58ND-45-10 in Soil Survey Investigations Report No. 2, pages 109-203.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. GBM
12/8/78

RHOADES SERIES

The Rhoades series consists of deep, well or moderately well drained, very slowly permeable soils formed in stratified loamy and clayey materials derived from saline-alkali soft shales. These soils are on upland plains, terraces and swales and have slopes of 0 to 25 percent. Mean annual temperature is 42° F, and mean annual precipitation is 16 inches.

Taxonomic Class: Fine, montmorillonitic Leptic Natriborolls.

Typical Pedon: Rhoades loam - grassland. (Colors are for dry soil unless otherwise stated.)

A2--0 to 4 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; moderate medium prismatic structure separating to moderate and strong coarse to fine platy; friable; many roots; common fine pores; peds coated with light gray (10YR 6/1) uncoated sand grains; neutral; abrupt smooth boundary. (2 to 5 inches thick)

B2t--4 to 11 inches; grayish brown (10YR 5/2) clay loam, very dark grayish brown (10YR 3/2) moist; strong coarse columnar structure separating to moderate fine angular blocky in lower part; extremely hard, firm, sticky, plastic; common roots between columns; few medium common fine pores; columns capped with a light gray (10YR 7/1) layer; dark grayish brown (10YR 4/2) clay films on faces of peds; few gypsum crystals in lower part; moderately alkaline; clear wavy boundary. (5 to 20 inches thick)

B3--11 to 16 inches; grayish brown (2.5Y 5/2) clay loam, very dark grayish brown (2.5Y 3/2) moist; weak coarse prismatic structure separating to moderate medium and fine subangular blocky extremely hard, firm, common fine pores; thin clay films; common gypsum crystals; many soft masses of lime; noneffervescent between lime masses; strongly alkaline; gradual wavy boundary. (0 to 15 inches thick)

B3cs--16 to 35 inches; light brownish gray (2.5Y 6/2) clay loam, olive brown (2.5Y 4/4) moist; weak coarse prismatic structure separating to moderate medium and fine subangular blocky; extremely hard, firm; common fine pores; few masses of lime; common coarse and fine gypsum crystals; strong effervescence; strongly alkaline; gradual boundary. (10 to 25 inches thick)

C2--35 to 49 inches; olive gray (5Y 5/2) clay loam, olive (5Y 4/3) moist; weak fine and medium subangular blocky structure; extremely hard, firm; few large nests of gypsum crystals; common soft masses of lime; strong effervescence, strongly alkaline; clear wavy boundary. (10 to 25 inches thick)

Cr--49 to 60 inches; olive gray (5Y 5/2) soft massive silty clay shale; strong effervescence.

Type Location: Stark County, North Dakota; 380 feet south and 125 feet west of the NE corner of the SE1/4 of sec. 11, T. 140 N., R. 99 W.

Range in Characteristics: Depth to soft shale is over 40 inches. Some pedons have thin A1 horizons. The A1 and A2 horizons have a combined thickness of 1 to 5 inches. The A2 horizon has hue of 10YR, value of 4 through 6 and 2 through 5 moist, and chroma of 2 dry or moist. The A1 and A2 horizons are loam, silt loam or very fine sandy loam, fine sandy loam, silty clay loam, clay loam, or silty clay. The B2t horizon has hue of 10YR or 2.5Y, value of 3 through 5 and 2 or 3 moist, and chroma of 2 dry or moist. It is silty clay loam, clay loam, clay or silty clay averaging between 35 and 50 percent clay. It has coarse or medium columnar structure that separates to blocky in some pedons. It is firm or very firm. Clay films and organic stains are on faces of columns. Some pedons have B3cs horizons.

The C horizon has hue of 2.5Y or 5Y, value of 5 through 7 and 4 or 5 moist and chroma of 2 through 4 dry or moist. It commonly is clay loam, loam, silty clay loam, silty clay or clay. It has few to common salt crystals.

RHOADES SERIES--

Competing Series: These are the Exline series in the same family and the Absher, Auger, Belfield, Daglum and Lennep series. Exline soils have A horizons with color chroma of 1 and have formed in lacustrine sediments. Absher soils lack mollic epipedons. Adger and Daglum soils lack visible gypsum crystals or nests within depths of 16 inches. Belfield and Lennep soils have tonguing or interfingering of A2 material extending over 2 inches into their natric horizons.

Geographic Setting: Rhoades soils are on nearly level to sloping upland plains, terraces and concave swales. Slope gradients commonly are 1 to 9 percent but range from 0 to 25 percent. The soils formed in stratified loamy and clayey materials derived from saline-alkali soft shales. Mean annual temperature ranges from 40 to 45° F, and mean annual precipitation from 13 to 17 inches.

Geographically Associated Soils: The competing Belfield and Daglum soils are in complexes with Rhoades soils in many localities. Arnegard, Grail, Lawther, Morton, Regent and Vebar soils are on nearby swales, terraces and uplands. All lack the A2 horizons and B2t horizons that have strong columnar structure.

Drainage and Permeability: Moderately well and well drained. Runoff is slow or moderately rapid, depending upon slope. Permeability is very slow.

Use and Vegetation: Mostly in grassland used for range and pasture. Native vegetation is short and mid prairie grasses such as western wheatgrass, blue grama, sedges, and also some legumes, prickly pear and clubmoss. Some areas are cultivated mostly to small grains.

Distribution and Extent: Southwestern North Dakota, northwestern South Dakota, and eastern Montana. The soil is extensive.

Series Established: McKenzie County, North Dakota, 1932.

Remarks: The series, as presently defined, includes some soils formerly placed in the Moline and Wade series. Soils formerly included in the Rhoades series but now separated are in the Absher, Beckton, Belfield and Daglum series.

Additional Data: Type location lab sample number S61ND-45-6. Other lab samples S54SD-53-1, S54SD-53-2 and S61ND-45-8.

National Cooperative Soil Survey
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Established Series
Rev. JCM/SHB
11/76

SAVAGE SERIES

The Savage series consists of deep, well drained, clayey soils that formed in alluvium. Savage soils are on fans and terraces. The mean annual precipitation is about 15 inches, and the mean annual air temperature is 43°F.

Taxonomic Class: Fine, montmorillonitic Typic Argiborolls.

Typical Pedon: Savage silty clay loam, grassland. (Colors are for dry soil unless otherwise noted.)

A1--0 to 2 inches; dark grayish brown (2.5Y 4/2) heavy silt loam, very dark brown (2.5Y 2/2) moist; weak thick platy structure; hard, friable, slightly sticky and plastic; many fine and few medium roots; many fine and medium pores; neutral (pH 7.4); clear wavy boundary. (2 to 7 inches thick)

B21t--2 to 6 inches; grayish brown (2.5Y 5/2) heavy silty clay loam, very dark grayish brown (2.5Y 3/2) moist; moderate medium and coarse prismatic structure that separates to moderate medium blocky; very hard, firm, very sticky and very plastic; thin patchy clay films on faces of peds; common very fine roots; common fine tubular pores; neutral (pH 7.4); clear wavy boundary. (2 to 4 inches thick)

B22t--6 to 16 inches; dark grayish brown (2.5Y 4/2) silty clay, very dark grayish brown (2.5Y 3/2) moist; moderate medium and coarse prismatic structure that separates to strong medium blocky; very hard, firm, very sticky and very plastic; continuous clay films on faces of peds; common very fine roots; common fine tubular pores; mildly alkaline (pH 7.6); clear wavy boundary. (10 to 18 inches thick)

B3ca--16 to 23 inches; grayish brown (2.5Y 5/2) silty clay, dark grayish brown (2.5Y 4/2) moist; strong coarse prismatic structure that separates to moderate medium and coarse blocky; very hard, very firm, very sticky and very plastic; few very fine and fine roots; few fine pores; moderately effervescent; common fine threads and soft medium masses of lime; moderately alkaline; gradual wavy boundary. (5 to 7 inches thick)

C1ca--23 to 29 inches; olive (5Y 5/3) silty clay, olive (5Y 4/3) moist; weak coarse prismatic structure that separates to moderate medium blocky; very hard, very firm, very sticky and very plastic; few fine roots; common very fine and fine pores; strongly effervescent; common fine threads and medium soft masses of lime; moderately alkaline; gradual wavy boundary. (5 to 15 inches thick)

C2--29 to 39 inches; olive (5Y 5/3) light silty clay, olive (5Y 4/3) moist; weak medium blocky structure; very hard, very firm, very sticky and very plastic; few fine roots; common fine pores; strongly effervescent; common fine threads and medium soft masses of lime; moderately alkaline; diffuse irregular boundary. (5 to 15 inches thick)

C3--39 to 61 inches; pale olive (5Y 6/3) silty clay loam, olive (5Y 4/3) moist; massive; hard, firm, sticky and plastic; few pores and fine roots; strongly effervescent; few fine soft masses of lime; moderately alkaline.

Type Location: Big Horn County, Montana; 180 feet west of trail; 860 feet east and 950 feet north of the SW corner of section 8, T.9S., R.35E.

Range in Characteristics: The mean annual soil temperature ranges from 42° to 47°F. The control section contains 35 to 45 percent clay. The hue ranges from 7.5YR through 2.5Y. The mollic epipedon is 8 to 16 inches thick and contains part or all of the argillic horizon. Depth to calcareous material is 10 to 22 inches.

The A horizon has value of 4 or 5 dry, 2 or 3 moist, and chroma of 2 or 3. It is mainly clay loam, silty clay loam, loam or silt loam.

The B2t horizon has value of 4 or 5 dry, 3 or 4 moist, and chroma of 2 or 3. The lower values are part of the mollic epipedon. This horizon is clay, silty clay, or heavy silty clay loam and has 35 to 45 percent clay. It is neutral through moderately alkaline.

The C horizon is clay, silty clay, or silty clay loam and has some stratification of coarser material. Some pedons have gravelly or very gravelly layers below depth of 40 inches. Some pedons contain gypsum below depth of 50 inches.

Competing Series: These are the Absarokee, Bearpaw (T), Danvers, Delson, Herm, Mondamin, Regent, Ricot (T), and Work series. Absarokee and Regent soils have soft bedrock at depths of 20 to 40 inches. Bearpaw soils have glacial till with high bulk density at depths of less than 40 inches. Danvers soils have a calcic horizon. Delson and Herm soils are noncalcareous throughout. Mondamin soils formed in fine textured glaciolacustrine beds (see Remarks). Ricot soils have hue of 7.5YR or redder. Work soils have more than 15 percent fine sand and coarser in their control section.

Savage Series

Geographic Setting: Savage soils are nearly level to strongly sloping and are on terraces of rivers and streams on sloping alluvial fans at elevations of 2,200 to 4,500 feet. They formed in calcareous alluvium or loess of mixed mineral origin, having a high proportion of silt and very fine sand and a low proportion of fine and coarser sands. The climate is cool semiarid with a mean annual temperature of 40° to 45°F. and average summer temperature warmer than 65°F. The mean annual precipitation is 12 to 19 inches with areas receiving less than 14 inches having cooler temperatures or lower evaporation. Most of the precipitation falls in spring or early summer. The (32°F.) growing season is 100 to 130 days.

Geographically Associated Soils: These are the Farland, Morton, and Xavier soils and the competing Regent soils. Farland and Morton soils have light silty clay loam B2t horizons. Xavier soils have solums with the base of B2t horizons extending to depths of less than 10 inches.

Drainage and Permeability: Well drained; slow or medium runoff; moderately slow or slow permeability.

Use and Vegetation: Use is mainly for irrigated and nonirrigated cropland. Some areas are still in grass. Principal native vegetation is mixed short and mid grasses, mainly western wheatgrass, prairie junegrass, green needlegrass, and forbs and shrubs.

Distribution and Extent: Widely distributed throughout Montana and in western North Dakota and South Dakota.

Series Established: Lower Yellowstone Area, Montana, 1932.

Remarks: No morphological basis has been established to separate the Mondamin soils from the Savage series.

National Cooperative Soil Survey
U. S. A.

Established Series
Rev. GBM
6/6/80

SEARING SERIES

The Searing series consists of deep, well drained, moderately permeable soils that formed in material weathered from porcelanite over scattered porcelanite. These soils are on uplands and have slopes ranging from 1 to 15 percent. Mean annual temperature is 42° F, and mean annual precipitation is 15 inches.

Taxonomic Class: Fine-loamy over fragmental, mixed Typic Haploborolls.

Typical Pedon: Searing loam - cultivated. (Colors for dry soil unless otherwise stated.)

Ap--0 to 6 inches; brown (7.5YR 4/2) loam, dark brown (7.5YR 3/2) moist; weak medium subangular blocky and moderate medium and fine granular structure; slightly hard, friable; common roots, many fine pores; neutral; abrupt smooth boundary. (4 to 10 inches thick)

B21t--6 to 12 inches; dark reddish gray (5YR 4/2) loam, dark reddish brown (5YR 3/2) moist; moderate coarse prismatic structure parting to moderate coarse and medium angular blocky; hard, friable; common roots, many fine pores; many clay films of dark brown (7.5YR 3/2) moist; neutral; clear wavy boundary.

B22--12 to 16 inches; reddish brown (5YR 4/3) loam, dark reddish brown (5YR 3/3) moist; weak coarse prismatic structure parting to moderate coarse and medium angular blocky; hard, friable; common fine roots and pores; a few porcelanite chips; mildly alkaline; clear wavy boundary. (B2 horizon is 6 to 16 inches thick)

C1--16 to 23 inches; reddish yellow (5YR 6/6) loam, yellowish red (5YR 4/6) moist; weak coarse and medium subangular blocky structure; slightly hard, friable; few roots; common fine pores; 10 percent porcelanite chips; strong effervescence; moderately alkaline. (4 to 15 inches thick)

C2--23 to 28 inches; reddish yellow (5YR 6/6) channery loam, yellowish red (5YR 5/6) moist; weak fine subangular blocky structure; slightly hard, friable; about 50 percent partly weathered hard porcelanite chips; strong effervescence; moderately alkaline; clear wavy boundary. (0 to 5 inches thick)

C3--28 to 60 inches; yellowish red (5YR 5/6) shattered hard beds of platy porcelanite and clinkers with some sandy material between the layers; strong effervescence.

Type Location: Bowman County, North Dakota; about 1/4 mile north of Gasgoyne; 805 feet east and 2,595 feet north of the SW corner of sec. 33, T. 131 N., R. 99 W.

Range in Characteristics: The thickness of solum and depth to free carbonates ranges from 10 to 24 inches and depth to shattered reddish clinker or porcelanite ranges from 20 to 40 inches. Porcelanite, as sand grains or channery fragments, is mixed throughout the solum in some pedons.

The A horizon has hue of 5YR, 7.5YR, or 10YR, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3. It is loam, silt loam, or clay loam.

The B horizon has hue of 5YR, 7.5YR, or 10YR, value of 4 to 6 and 3 or 4 moist, and chroma of 2 to 4. It is a loam, silt loam, or clay loam averaging between 18 and 30 percent clay. It has weak to strong prismatic structure that parts to moderate or strong blocky structure. There is only a slight clay increase in the B horizon. Clay films are lacking in some pedons. Pedons formed in noncalcareous porcelanite beds, are low in lime but are included in the range of the series.

The upper C horizon is loam or clay loam with 5 to 30 percent porcelanite coarse fragments.

The lower C horizon is shattered porcelanite with some sandy material on flat surfaces. White lime coatings are on surfaces in some pedons.

SEARING SERIES--2

Competing Series: There are no other soils in this family. Similar soils are the Brandenburg, Ringling, Stady, and Twin Creek. Brandenburg and Ringling soils have porcelanite at a depth of less than 20 inches. Stady soils have gravel and sand at depths of 20 to 40 inches. Twin Creek soils formed in alluvium from red sandstone and shale and, in addition, lack fragmental material within depths of 40 inches.

Geographic Setting: Searing soils are on nearly level to rolling uplands with slope gradients of 1 to 15 percent. The soil formed in sedimentary material weathered in place on porcelanite or clinkers from burned-out coal veins. The climate is cool, semiarid, with mean annual temperature of 38° to 45° F, and mean annual precipitation of 13 to 17 inches. Three-fourths of the moisture falls in the spring and summer.

Geographically Associated Soils: These are the Brandenburg, Flasher, Ringling, and Yawdim soils on the steep slopes and hills; Amor, Morton, Sen, Regent, and Vebar soils on nearby sloping areas and the Grail, Arnegard, Shambo, and Farland on nearly level swales and terraces. The noncompeting Amor, Flasher, Morton, Sen, Regent, Vebar, and Yawdim soils do not have fragmental material at a depth of 20 to 40 inches.

Drainage and Permeability: Well drained. Runoff is medium. Permeability is moderate.

Use and Vegetation: Use for small grains, some row crops, hay, and range. Native vegetation: Medium and short prairie grasses, such as western wheatgrass, green needlegrass, blue grama, and some forbs.

Distribution and Extent: Widely distributed in small tracts in the sedimentary plains of western North Dakota, eastern Montana, and Wyoming. The series is of moderate extent.

Remarks: The Searing series was formerly classified fine-loamy, mixed Typic Haploborolls.

Series Established: Sheridan County, Wyoming, 1932.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. COC/SHB
11/76

STRAW SERIES

The Straw series consists of deep, well drained soils that formed in mixed alluvium. Straw soils are nearly level to moderately sloping and are on low terraces alluvial fans and floodplains. The mean annual precipitation is about 16 inches and the mean annual air temperature is about 43°F.

Taxonomic Class: Fine-loamy, mixed Cumulic Haploborolls.

Typical Pedon: Straw loam, cultivated. (Colors are for dry soil unless otherwise noted.)

Ap--0 to 10 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; moderate fine crumb structure; slightly hard, very friable, slightly sticky and slightly plastic; many fine and few medium roots; many fine and medium pores; slightly effervescent; mildly alkaline (pH 7.6); clear wavy boundary. (4 to 8 inches thick)

A12--10 to 27 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; weak coarse prismatic structure; slightly hard, very friable, slightly sticky and slightly plastic; common fine and very fine roots; many fine and very fine pores; strongly effervescent; moderately alkaline (pH 8.0); diffuse boundary. (16 to 26 inches thick)

C1--27 to 38 inches; grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; massive; hard, very friable, slightly sticky and slightly plastic; few fine and very fine roots; many fine and very fine pores; few fine masses of segregated lime; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

C2--38 to 54 inches; light brownish gray (2.5Y 6/2) silt loam, dark grayish brown (2.5Y 4/2) moist; massive; hard, very friable, slightly sticky and slightly plastic; few fine and very fine roots; common fine and very fine pores; strongly effervescent; moderately alkaline (pH 8.3); clear smooth boundary.

IIC3--54 to 66 inches; light brownish gray (10YR 6/2) loamy sand, dark grayish brown (10YR 4/2) moist; massive; soft, very friable, nonsticky and nonplastic; strongly effervescent; mildly alkaline (pH 7.6).

Type Location: Cascade County, Montana; 500 feet south and 100 feet west of NE corner of the SE1/4 of section 25, T.18N., R.6E.

Range in Characteristics: The mollic epipedon ranges from 16 to 40 inches thick. The 10- to 40-inch control section averages 20 to 35 percent clay. Some pedons have thin lenses of sandy loam and loamy sand at depths of less than 40 inches. The mean annual soil temperature is 40° to 46°F. The soil is usually calcareous throughout but some pedons are noncalcareous in the upper 7 inches. The hue of the soil is 10YR or 2.5Y.

The A horizon has value of 3 through 5 dry and 2 or 3 moist. It is loam, silt loam, clay loam or sandy clay loam. In some pedons, lime threads, films, and nodules are present in the lower part of the A12 horizon and in the C horizon. Some pedons have old buried A horizons in the underlying material. The C horizon has lenses of nonconforming texture in some pedons. Reaction is neutral to moderately alkaline in the A horizon and mildly or moderately alkaline in the C horizon.

Competing Series: These are the Brycan, Frolic, Jodero, McGaffey and Nutrioso series in the same family, and the Havrelon series. Brycan soils have a cambic horizon, are noncalcareous throughout the solum and have chroma of 3 through 6 in the B2 and C horizons. Frolic soils are noncalcareous. Havrelon soils lack a mollic epipedon. Jodero soils have a mollic epipedon more than 40 inches thick. McGaffey soils have hue of 5YR or redder. Nutrioso soils have a mollic epipedon less than 24 inches thick.

Geographic Setting: Straw soils are nearly level to moderately sloping and are on low terraces, alluvial fans and flood plains with rare or occasional flooding, and are at elevations of 2,500 to 4,500 feet. They formed in calcareous loamy alluvium from mixed rock sources. The climate is cool with a mean annual temperature of 40° to 46°F. The mean annual precipitation is 13 to 19 inches, most of which falls in spring or early summer. The (32°F.) growing season is 105 to 135 days.

Geographically Associated Soils: These are the Banks, Korchea, Nesda and Rivra soils and the competing Havrelon soils. All of these soils except Korchea lack mollic epipedons. Korchea soils have a mollic epipedon less than 16 inches thick.

Drainage and Permeability: Well drained; slow runoff; moderate permeability.

Use and Vegetation: Straw soils are used for dryland cropland, irrigated cropland and for range. The primary native vegetation is rough fescue, western wheatgrass, needleandthread, little bluestem, bluebunch wheatgrass, green needlegrass, forbs and shrubs.

Straw Series

Distribution and Extent: Eastern Montana and possibly in Wyoming and North Dakota. The series is of moderate extent.

Series Established: Judith Basin County, Montana, 1960.

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U. S. A.

Established Series
Rev. GBM
6/28/79

VEBAR SERIES

The Vebar series consists of well drained, moderately rapidly permeable soils that formed in residuum weathered from soft calcareous sandstone. Depth to soft standstone ranges from 20 to 40 inches. These soils are on uplands and have slopes ranging from 0 to 50 percent. Mean annual temperature is 42° F, and mean annual precipitation is 16 inches.

Taxonomic Class: Coarse-loamy, mixed Typic Haploborolls.

Typical Pedon: Vebar fine sandy loam - on a SW facing plane slope of 5 percent in native grassland. (Colors are for dry soil unless otherwise stated. Where described the soil was moist throughout.)

A1--0 to 5 inches; dark grayish brown (10YR 4/2) fine sandy loam, very dark brown (10YR 2/2) moist; weak coarse and medium prismatic structure parting to weak fine subangular blocky structure; slightly hard, very friable, slightly sticky, nonplastic; many roots and fine pores; slightly acid; gradual wavy boundary. (4 to 10 inches thick)

B21--5 to 14 inches; dark grayish brown (10YR 4/2) fine sandy loam, dark brown (10YR 3/3) moist; moderate coarse prismatic structure parting to weak medium subangular blocky structure; slightly hard, very friable, slightly sticky, nonplastic; many fine roots and pores; slightly acid; gradual wavy boundary. (4 to 12 inches thick)

B22--14 to 19 inches; brown (10YR 5/3) fine sandy loam, brown (10YR 4/3) moist; moderate coarse prismatic structure parting to weak medium and fine subangular blocky structure; slightly hard, very friable, slightly sticky, nonplastic; common fine roots and pores; neutral; clear wavy boundary. (0 to 10 inches thick)

B3--19 to 26 inches; brown (10YR 5/3) fine sandy loam, brown (10YR 4/3) moist; weak coarse prismatic structure; slightly hard, very friable, nonsticky, nonplastic; few roots, common fine pores; neutral; clear, very wavy boundary. (0 to 12 inches thick)

C--26 to 32 inches; light yellowish brown (2.5Y 6/4) fine sandy loam, light olive brown (2.5Y 5/4) moist; massive; slightly hard, very friable, nonsticky, nonplastic; few hard sandstone fragments; few small sandstone fragments; few small lime accumulations; strong effervescence (2 percent lime); mildly alkaline; clear wavy boundary. (2 to 10 inches thick)

Cr--32 to 60 inches; light yellowish brown (2.5Y 6/4) soft massive calcareous sandstone; lense of hard sandstone 3 inches thick at 43 inches; some lime accumulations around hard fragments; strong effervescence (6 percent lime) in upper part; slight effervescence in lower part (1 percent lime); moderately alkaline.

Type Location: Stark County, North Dakota; about 6 miles south and 5 1/2 miles east of Dickinson; 355 feet south and 70 feet east of the NW corner of the NE quarter of sec. 16, T. 138 N., R. 95 W.

Range in Characteristics: Solum thickness typically is about 26 inches and ranges between 15 and 40 inches. Depth to soft sandstone ranges from 20 to 40 inches. The mollic epipedon ranges from 7 to 16 inches in thickness. In most pedons the soft sandstone contains free carbonates. Some pedons have an accumulation of lime at the bottom of the solum or the upper part of the sandstone.

The A1 horizon has hue of 10YR, value of 3 to 5 and 2 or 3 moist, and chroma of 2 or 3 dry or moist. It typically is fine sandy loam, but some is sandy loam or light loam. The A horizon ranges from slightly acid to mildly alkaline.

The B2 horizon has hue of 10YR or 2.5Y, value of 4 to 6 and 3 or 4 moist, and chroma of 2 to 4 dry or moist. It typically is fine sandy loam, but some is sandy loam or light loam. The B horizon has weak or moderate coarse or medium prismatic structure that parts easily to weak or moderate subangular blocky structure. It is slightly acid to mildly alkaline in the upper part and neutral to moderately alkaline in the lower part.

VEBAR SERIES--2

The C horizon has hue of 10YR, 2.5Y or 5Y, value of 5 to 7 and 4 to 6 moist, and chroma of 2 to 4 dry or moist. Typically it is fine sandy loam or loamy fine sand, but some is sandy loam. The soft sandstone crushes to loamy fine sand or fine sandy loam. Thin ledges or concretion-like pipes of hard sandstone are in some pedons.

Competing Series: These are the Belain, Bitterroot, Hopley, Mott, Panguitch, Relan, Tally, and Victor series in the same family and Cohagen, Lihen, Manning, Parshall, Rhame, Telfer, and Velva series. Bitterroot and Hopley soils are dominately loam in the series control section. Belain soils have a lithic contact of depth of 20 to 40 inches. Mott, Panguitch, Tally and Victor soils lack paralithic beds between depths of 20 and 40 inches. In addition, Panguitch soils contain 20 to 35 percent by volume of coarse fragments and are formed in alluvium derived from volcanic materials; and the Victor soils have a sandy-skeletal substrata at depths of about 40 inches. Relan soils have hue of 7.5YR or redder throughout the series control section. Cohagen soils lack mollic epipedons and have paralithic beds at depths of less than 20 inches. Lihen, Manning, Parshall, Telfer and Velva soils lack paralithic beds between depths of 20 and 40 inches. In addition, the Lihen and Parshall soils have mollic epipedons more than 16 inches thick; and Telfer soils are sandy and the Velva soils have an irregular decrease in organic matter content; and Manning soils have sand and gravel at depths of 16 to 40 inches. Rhame soils are usually dry.

Geographic Setting: Vebar soils are on nearly level to rolling uplands. Slopes are plain or convex. Slope gradients range from 0 to 50 percent. The soils formed in residuum weathered from soft calcareous sandstone. The climate is cool and semiarid. Mean annual temperature ranges from 38 to 45° F and mean annual precipitation from 14 to 17 inches. Most of the precipitation comes in the spring and summer.

Geographically Associated Soils: These are the competing Cohagen, Parshall and Tally soils and the Armor, Arnegard, Flasher, Morton, Sen and Shambo soils. Cohagen soils are on steep hilltops and ridges. Parshall and Tally soils are on concave swales, terraces, and less sloping areas. Amor, Arnegard, Morton, Sen and Shambo soils contain more clay and silt and less sand than the Vebar soils. They are on nearby uplands, swales, and terraces. Flasher soils have paralithic beds at depths of less than 20 inches and have sandy textures. They are on nearby hilltops and ridges.

Drainage and Permeability: Well drained. Surface is slow or medium. Permeability is moderately rapid above paralithic beds.

Use and Vegetation: Soils are cropped to corn and small grains. Some is used for hay or pasture. Native grasses are needleandthread, prairie sandreed, prairie junegrass and sun sedge.

Distribution and Extent: Western North Dakota, eastern Montana, northwestern South Dakota, and western Nebraska. The series is extensive.

Series Established: Wibaux County, Montana, 1943.

Additional Data: S 54NDak-45-2, pages 258 and 259, Soil Survey Investigations No. 2.

National Cooperative Soil Survey
U.S.A.

Replace Midway series

Established Series
Rev. GBM

WAYDEN SERIES

The Wayden series consists of well drained, slowly permeable soils that formed in soft alkaline shales. These soils are shallow to soft shale. They are on sedimentary uplands and have slopes ranging from 0 to 50 percent. Mean annual temperature is 43° F, and mean annual precipitation is 15 inches.

Taxonomic Class: Clayey, montmorillonitic (calcareous) frigid, shallow Typic Ustorthents.

Typical Pedon: Wayden silty clay - near crest of low rise on a 2 percent south-facing slope in native grass. (Colors are for dry soil unless otherwise stated. When described the soil was moist throughout.)

A1--0 to 3 inches; light gray (2.5Y 7/2) silty clay, grayish brown (2.5Y 5/2) moist; strong very fine granular structure; hard, friable, sticky, and plastic; many fine and very fine roots; slight effervescence; moderately alkaline; clear wavy boundary. (1 to 6 inches thick)

C1--3 to 7 inches; light gray (5Y 7/2) silty clay, olive gray (5Y 5/2) moist; moderate coarse and medium subangular blocky structure parting to moderate fine subangular blocky; very hard, friable, sticky, and plastic; common fine and very fine roots; common fine pores; strong effervescence; moderately alkaline; gradual smooth boundary. (4 to 6 inches thick)

C2--7 to 15 inches; light gray (5Y 7/2) silty clay, olive gray (5Y 5/2) moist; weak coarse subangular blocky structure parting to moderate fine subangular blocky; very hard, friable, sticky, and plastic; common fine and very fine roots; many gypsum crystals; few soft shale chips; slight effervescence; moderately alkaline; gradual wavy boundary. (5 to 12 inches thick)

Cr--15 to 60 inches; pale yellow (5Y 5/3) stratified silty clay shale, pale olive (5Y 6/3) moist; yellowish brown (10YR 5/6) moist stains on plates in places; extremely hard, very fine, slakes in water; slight effervescence; moderately alkaline.

Type Location: Bowman County, North Dakota; about 1 mile east and 1 mile south of Bowman; 475 feet north and 130 feet west of the southeast corner of sec. 13, T. 131 N., R. 102 W.

Range in Characteristics: The depth to soft shale ranges from 10 to 20 inches.

The A1 horizon has hue of 2.5Y or 5Y, value of 5 to 7, 3 to 5 moist, and chroma of 2 or 3. It is silty clay, silty clay loam, clay, or clay loam averaging between 35 and 50 percent clay. It is mildly to strongly alkaline.

The C horizon has hue of 2.5Y or 5Y, value of 5 to 8, 4 to 6 moist, and chroma of 1 to 4. It is silty clay, silty clay loam, clay, or clay loam averaging between 35 and 50 percent clay. It is mildly to strongly alkaline.

Competing Series: These are the Norbert and Ruko soils in the same family; and the Cabba, Dilts, Dimyaw, Hillon, Kuro, Lambert, Lisam, Moreau, Yawdim, and Zahill soils. Norbert, Dilts, and Lisam soils average between 50 to 60 percent clay. In addition, the Dilts soils are more acid. Ruko soils have 10YR hue and are strongly or violently effervescent throughout the C horizon. Dimyaw soils do not have a paralithic contact. Cabba, Hillon, Lambert, and Zahill soils contain less than 35 percent clay. Kuro soils formed in stratified weak red and pale yellow or in red, strongly effervescent shale. Moreau soils have a mollic epipedon and are moderately deep to shale. Yawdim soils are drier.

Geographic Setting: Wayden soils are on nearly level to very steep sedimentary uplands. Slope gradients range from 0 to 50 percent. The Wayden soils formed in calcareous clayey material weathered from soft shales. The mean annual precipitation is 13 to 17 inches. The mean annual temperature is 39° to 45° F.

Geographically Associated Soils: These include the competing Cabba and Moreau and the Amor, Belfield, Brandenburg, Flasher, Morton, Regent, Rhoades, Ringling, Sen, and Vebar series. Cabba

WAYDEN SERIES--2

and Moreau soils are on nearby similar positions to Wayden. Soils on the nearby uplands include Amor, Belfield, Morton, Regent, Rhoades, Sen, and Vebar soils. All have thicker sola, mollic epipedons, and cambic or argillic horizons. Brandenburg and Ringling soils have porcelanite at shallow depths. Flasher soils are sandy and formed in nearby sandy sedimentary beds.

Drainage and Permeability: Well drained. Medium or rapid runoff. Slow permeability.

Use and Vegetation: Used mainly for range, less commonly for growing small grains. Native vegetation includes western wheatgrass, little bluestem, needleandthread, sedges, and forbs.

Distribution and Extent: Eastern and northern Montana, western North Dakota, northwestern South Dakota. The soil is extensive.

Series Established: Bowman County, North Dakota, 1969.

Additional Data: S61ND-45-3.

National Cooperative Soil Survey
U.S.A.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Rattlesnake Butte, North Dakota

INTERPRETIVE RATINGS FOR SOIL USES

Map Symbol (SCS) (1)	Soil Name (2)	Suitability						Degree of Limitation				
								Ponds				
		Dryland Farming (3) 1/	Irrigation (4)	Topsoil (5)	Sand/ Gravel (6)	Road Fill (7)	Range/ Wildlife (8) 1/	Location (9)	Embankment (10)	Road Location (11)	Shallow Excavations (12) 1/	Building Sites (13) 1/
AtA-ArB	Arnegard	Good	Good	Excellent	Not Suitable	Fair-Poor	Good	Fair	Fair	Slight	Slight	Moderate
Bad-Bf	Bainville	Poor	Not Suitable	Poor	Not Suitable	Fair-Poor	Fair	Good	Fair	Mod-high	Slight	Moderate
Bk	Beckton	Fair	Not Suitable	Fair	Not Suitable	Fair-Poor	Poor	Fair	Fair	Slight	Moderate	Moderate
BoA-BoB	Belfield	Good	Fair-Good	Good	Not Suitable	Fair-Poor	Good	Good	Fair	Mod-high	Slight	Moderate
CbC-CbD	Chama	Fair	Not Suitable	Fair	Not Suitable	Poor	Fair	Poor	Poor	Moderate	Slight	Moderate
FaB-FgA	Farland	Good	Suitable	Good	Not Suitable	Poor	Good	Good	Fair	Moderate	Slight	Moderate
FiC-Fm-Fr	Flasher	Poor	Not Suitable	Fair	Not Suitable	Good-Fair	Fair	Poor	Fair	Slight	Severe	Slight
CrA-GrB	Crail	Good	Suitable	Excellent	Not Suitable	Poor	Fair	Good	Stable	Moderate	Slight	Moderate
Sv	Havre	Good	Suitable	Fair	Not Suitable	Fair	Fair	Good	Fair	Moderate	Slight	Moderate
Hn	Hoven	Poor	Not Suitable	Poor	Not Suitable	Fair-Poor	Poor	Good	Fair	Mod-high	Severe	Severe
LiC	Lihen	Poor	Suitable	Good	Find & Med. Sands	Fair-Poor	Fair	Poor	Fair	Slight	Severe	Slight
BaD-Bf	Midway	Poor	Not Suitable	Poor	Not Suitable	Fair-Poor	Poor	Good	Fair	Mod-high	Severe	Severe
MeA-MeB	Moreau	Fair	Not Suitable	Fair	Not Suitable	Fair-Poor	Poor	Good	Fair	Mod-high	Severe	Severe
MoC-MpC2	Morton	Good	Suitable	Good	Not Suitable	Fair-Poor	Fair	Good	Fair	Moderate	Moderate	Moderate
VpB	Parshall	Good	Suitable	Good	Fine Sand	Fair-Poor	Good	Poor	Fair	Slight	Slight	Slight

1/ Ratings based on BLM criteria. All other ratings based on data from Soil Conservation Service soil surveys.

UNITED STATES
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Rattlesnake Butte, North Dakota

INTERPRETIVE RATINGS FOR SOIL USES

Map Symbol (SCS) (1)	Soil Name (2)	Suitability						Degree of Limitation				
								Ponds				
		Dryland Farming (3) 1/	Irrigation (4)	Topsoil (5)	Sand/ Gravel (6)	Road Fill (7)	Range/ Wildlife (8) 1/	Location (9)	Embankment (10)	Road Location (11)	Shallow Excavations (12) 1/	Building Sites (13) 1/
PrA-PrB	Promise	Fair	Not Suitable	Good	Not Suit-able	Fair-Poor	Poor	Good	Fair	Mod-high	Severe	Severe
ReA-ReB	Regent	Fair	Not Suitable	Good	Not Suit-able	Fair-Poor	Fair	Good	Fair	Mod-high	Severe	Moderate
RsA-RsB	Rhoades	Fair	Not Suitable	Fair	Not Suit-able	Fair-Poor	Poor	Good	Fair-Good	Mod-high	Severe	Severe
Sa	Saline Alluvial	Poor	Not Suitable	Not Suit-able	Not Suit-able	Poor	Poor	Fair	Poor	Mod-high	Severe	Severe
Sg	Savage	Fair	Fair-Good	Good	Not Suit-able	Fair-Poor	Poor	Good	Stable	Mod-high	Moderate	Moderate
Sm	Searing	Fair	Poor-Fair	Good	Not Suit-able	Fair-Poor	Fair	Good	Poor	Mod-high	Severe	Severe
So-Sp	Shale Outcrop	Poor	Not Suitable	Poor	Not Suit-able	Poor	Poor	Good	Fair	Mod-high	Severe	Severe
Sv-StA	Straw	Good	Suitable	Good	Not Suit-able	Fair-Poor	Good	Good-Fair	Fair	Moderate	Slight	Slight
VfD-VpB	Vebar	Good	Suitable	Good	Fine Sand	Fair-Poor	Fair	Poor	Fair	Slight	Slight	Slight
Wb	Wibaux	Poor	Not Suitable	Poor	Not Suit-able	Good-Fair	Poor	Good	Fair	Slight	Severe	Severe

1/ Ratings based on BLM criteria. All other ratings based on data from Soil Conservation Service soil surveys.

UNITED STATES
DEPARTMENT OF THE INTERIOR
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RATTLESNAKE BUTTE, NORTH DAKOTA
Table 74 ENGINEERING PROPERTIES OF SOILS
MEASUREMENTS AND INTERPRETATIONS

Map Symbol (1)	Soil Name (2)	Depth From Surface of Typical Profile (inches) (3)	Depth To		Hydrologic Soil Croup (6)	Shrink-Swell Potential (7)	Corrosivity		Classification			Coarse Fraction Percent (13)
			Bedrock (inches) (4)	Seasonal High Water Table (inches) (5)			Uncoated Steel (8)	Concrete (9)	USDA Text. (10)	Unified (11)	AASHO (12)	
ArA-ArB	Arnegard	0-30	-	-	B	Low	Mod.	Low	Loam, SiL	ML	A-4	-
		30-50	-	-	B	Low	Mod.	Low	Loam, FSL	ML-SM	A-4,A-2	
BaD-Bf	Bainville	0-60	<60	-	B	Low	Low	Low	Loam, SiL	ML	A-4	-
Bk	Beckton	0-11	-	-	B	Low	Low	Low	FSL	SM	A-2,A-4	-
		11-21	-	-	C	Mod.	Mod.	Low	SCL	SC	A-6	-
		21-50	-	-	D	Mod.	V. High	Low	SC	CL	A-6	-
BoA-BoB	Belfield	0-7	-	-	B	Mod.	Low	Low	L,CL	ML	A-4,A-6	-
BrA-BrB		7-37	-	-	C	Mod.	High	Low	CL,SiC	CL	A-6,A-7	-
CbC-CbD	Chama	0-50	-	-	B	Low	Low	Low	L,SiL	ML	A-4	-
FaB-FgA	Farland	0-50	-	-	B	Low	Low	Low	SiL	ML	A-4	-
		5-32	-	-	B	Mod.	Mod.	Low	SiCL	CL	A-6	-
		32-60	-	-	B	Mod.	Mod.	Low	L,CL	ML,CL	A-4,A-6	-
FiC-Fm-Fr	Flasher	0-4	10	-	B	Low	Low	Low	FSL	SM	A-2-4	-
		4-50	-	-	B	Low	Low	Low	FSL	SM	A-2-4	-
GrA-CrB	Grail	0-10	-	-	B	Mod.	Low	Low	SiCL	CL	A-6	-
		10-28	-	-	C	High	Low	Low	SiC	CL	A-7-6	-
		28-60	-	-	B	Mod.	Low	Low	SiCL	CL	A-6	-
Sv	Havre	0-60	-	<60	B	Low	Mod.	Low	L,SiL	ML	A-4	-
Ho	Hoven	0-3	-	-	B	Mod.	Low	Low	CL	CL	A-6	-
		3-60	-	-	C	High	V.High	Low	C	CH	A-7	-
LIC	Lihen	0-60	-	-	A	Low	Low	Low	LFS	SM	A-2	-
BaD-Bf	Midway	0-4	-	-	B	Mod.-High	Low	Low	CL	CL	A-7-6	-
		4-48	-	-	C	Mod.-High	High	Low	SiC	CL	A-7-6	-
MeA-MeB	Moreau	0-20	-	-	C	Mod.-High	V.High	Low	SiC	CL	A-7-6	-
		20-60	-	-	C	High	V.High	Low	C	MH-CH	A-7-6	-
MoC-MpC2	Morton	0-6	-	-	B	Low	Low	Low	L,SiL	ML	A-4	-
MrA-MsA-MrB		6-28	-	-	B	Mod.	Low	Low	CL	ML-CL	A-4	-
		28-55	-	-	B	Mod.	Low	Low	SiL	ML-CL	A-4,A-6	-
VpB	Parshall	0-30	-	-	B	Low	Low	Low	FSL	SM	A-2-4	-
		30-55	-	-	A	Low	Low	Low	FSL-LFS	SM	A-2,A-4	-
PrA-PrB	Promise	0-4	-	-	B	Mod.-High	Low	Low	SiC	CL	A-7-6	-
		4-22	-	-	C	High	High	Low	C	MH-CH	A-7-6	-
		22-50	-	-	C	High	High	Low	SiC	CL	A-7-6	-
ReA-ReB-RgA	Regent	0-7	-	-	C	Mod.	Mod.	Low	SiCL	CL	A-6	-
RgB-RgC		7-26	-	-	C	High	High	Low	SiC	CL	A-6	-
		26-60	-	-	C	Mod.	High	Low	SiCL	CL	A-6	-
RsA-RsB	Rhoades	0-3	-	-	A	Low	Low	Low	L	ML	A-4	-
		3-21	-	-	D	Mod.	High	Low	SiCL	CL	A-6	-
		27-55	-	-	D	Mod.	High	Low	CL-SiC	ML,CL	A-6,A-7	-
Sa	Saline Alluvial	0-60	-	>6	D	Mod.	High	Low	L-SiC	ML-ML,CL	A-4,A-7	-
So	Savage	0-6	-	-	B	Mod.	Low	Low	SiCL	CL	A-6	-
		6-26	-	-	C	Mod.-High	High	Low	SiC	CL	A-7-6	-
		26-55	-	-	C	Low-Mod.	High	Low	SiL-SiCL	ML-CL	A-4,A-6	-
ShA-Sm	Searing	0-22	-	-	B	Low	Low	Low	L-SiL	ML	A-4	-
		22-40	<22	-	-	-	-	-	-	-	-	-
So-Sp	Shale Outcrop	0-40	<40	-	B-C	Low-Mod.	Low-High	Low	Sl-SiC	SM-CL	A-2,A-6	-
Sv-StA	Straw	0-30	-	-	B	Low	Low	Low	L-SiL	ML	A-4	-
		30-60	-	-	B	Low	Low	Low	FSL-L	SM-ML	A-2,A-4	-
VfD-VpB-VpC	Vebar	0-35	-	-	B	Low	Low	Low	FSL	SM	A-2-4	-
		35-55	-	-	A	Low	Low	Low	LFS	SM	A-2-4	-
Wb	Wibaux	0-7	-	-	B	Low	Low	Low	L	ML	A-4	-
		7-40	>9	-	-	-	-	-	-	-	-	-

Note: Data from Soil Conservation Service Soil Surveys

SCREENABLE SOIL CHARACTERIZATION AS RELATED TO LAND RECLAMATION

By
William B. Peters, Luvern L. Resler, and Robert Vader 1/

Soil is characterized by laboratory methods to confirm judgment in field appraisals. There is a tendency among most laboratory activities to "over test"; i.e., perform too many or unnecessary tests on certain soils at the expense of not performing essential or critical testing on particular samples. Also, laboratory activities tend to emphasize comprehensive analyses of samples from master sites and neglect selection, sequence, and quality control in mass testing performed on a screenable basis. The latter-type testing is frequently handled as routine work utilizing the least dependable personnel and considered not worthy of competent and close supervision. Thus, too often the screenable laboratory testing becomes a liability rather than an asset in supporting land classification surveys. Because the screenable testing represents coverage of areas involving a high sampling density, it serves as an extremely important input into land categorization. Therefore, it should be administered for performance with respect to both quality and quantity commensurate with the goals and objectives of the investigation.

The objective of characterizing soil and overburden will be to support judgment in estimating land reclamation potential. (Overburden refers to the material consolidated or unconsolidated overlying minable resources in relation to surface mining.) Thus, the laboratory analyses must be performed on an action program basis and serve a practical purpose. Therefore, it is essential the physical and chemical characteristics of the soil and overburden be appraised in relation to edaphology; i.e., a medium suitable for the support of plant growth, rather than pedology.

Because the laboratory studies should serve to support field appraisals, all laboratory work should be closely coordinated with fieldwork. For full effectiveness, laboratory studies must be preceded by field studies. The number and type of studies will be determined by area conditions - particularly variability, the controlling project specifications, and needs. There should be a joint plan between field and laboratory investigations prior to taking of samples if maximum utilization of data is

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1/ Head and Soil Scientists, respectively, Land Utilization Section, Resource Analysis Branch, Division of Planning Coordination, U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado, U.S.A.

to be obtained. Problems should be studied rather than standard or routine tests made [Kellogg, 1962].

In submitting soil samples for laboratory characterizations, the laboratory should be furnished with pertinent field appraisals along with the tentative land utilization and quality designation. The soil and subsoil samples should represent genetic horizons with no more than 60-cm depth per sample. Substrata samples should represent uniform overburden with no more than 200 cm per sample unless drill hole diameters preclude obtaining sufficient material for laboratory and greenhouse studies.

The first priority in laboratory characterization should be accomplished by direct and indirect measurements for evaluating soil structure and its stability, soil-cation-exchange capacity or surface area, and soil reaction. After this is accomplished, then consideration should be given to testing that confirms, explains the causes of phenomena previously observed or predicted, reveals the presence of toxic elements (salinity level, boron content, alkali, acidity, reduction products, etc.), and indicates what and how much is required to cope with the soil deficiency under eventual field conditions and the moisture regimen expected to prevail [Peters, 1965].

Based on present knowledge of the area, the support characterizations should include field measurements for water movement and retention in soil and laboratory determinations for structure stability [Gardner, 1945] through measurements of floc volume and hydraulic conductivity of fragmented samples; moisture retentivity at 15-bars pressure; soil reaction by measurement of pH in water and neutral salt solution; soil salinity by measurement of specific electrical conductance of soil-water extracts; soil solution concentration and composition including sodium and calcium plus magnesium; cation exchange capacity; exchangeable cation status; residual gypsum; gypsum requirement; acid soluble carbonates; and others.

Samples collected in a reduced state may be alkaline or neutral while reduced, but acid when oxidized. Therefore, we should be on the "look-out" for such conditions and characteristics and assure reduced material is also analyzed in an aerated condition. Samples exhibiting acidity upon oxidation should be further analyzed to ascertain reduction products associated with the observed phenomenon.

Should conventional acidity; i.e., other than oxidation product, be encountered, the testing will be expanded to include acidity by measurement of neutral salt exchange acidity including aluminum, titratable acidity (amount of acidity neutralized at a selected pH), and soluble aluminum.

In screenable testing, the characterization for moisture retentivity at pressures less than 15 bars is not recommended unless a suitable use can be established. Measurements of moisture retentivity at 15-bars pressure are recommended because water content at this potential is usually correlated with several characteristics including amount and kind of clay, surface area, and cation exchange capacity. Moisture percentages at this potential would probably not be applicable in simulating water content at wilting for native vegetation.

In initial screening, diluted soil-water suspensions may be substituted for the time-consuming, saturated soil extracts in measuring electrical conductance provided limitations are ascertained. The reliability of higher moisture contents even as a tool in screening depends on the kind of salts present. For chloride salts, the results will be only slightly affected by the moisture content, but if sulfate or carbonate salts, which have relatively low solubility, are present in appreciable quantities, the apparent amount of soluble salt will depend on the soil-water ratio [Richards, 1954].

We do not concur in the practice of characterizing vast numbers of samples for textural class through measurements of particle-size distribution. This blanket laboratory analysis for soil textural class is neither required nor desired. Particle-size analysis should be limited to master site characterization, the occasional confirmation of field textural appraisals, and the training of new employees.

In the screenable characterization of samples, a procedure for the sequence of testing and screening of samples should encompass the following phases. Under Phase I of the scheme, all samples would be characterized for (1) soil structure stability through measurement of hydraulic conductivity on a fragmented sample basis during the 6th and 24th hours and volume of wet settled floccules, (2) moisture retentivity at 15-bars pressure, (3) electrical conductivity of soil-water extract, and (4) pH in water and in 0.01 molar calcium chloride solution.

In the second phase, <u>selected</u> samples suspected through the testing results of Phase 1 to be salt affected should be characterized for electrical conductivity of the saturation extract and sodium adsorption ratio.

In the third phase, <u>selected</u> samples suspected through the testing results of Phases I and II to be salt affected with respect to sodium will be tested for either gypsum requirement or residual gypsum, depending on salinity levels and associated pH values. Residual gypsum will be estimated by measuring calcium plus magnesium in a 1:5 soil-water ratio extract and reported in milliequivalents per 100 grams.

In the fourth phase, selected samples suspected through testing results of Phase I to be highly acid and low in base saturation and nonsaline should be further characterized for bases specifically sodium and calcium plus magnesium and acidity including the aluminum component extractable with a neutral salt; i.e., 1.0N potassium chloride. This will enable computation of effective soil-cation-exchange capacity; i.e., CEC at soil pH and the exchangeable aluminum percentage of this CEC.

In the fifth phase, selected samples having been characterized during Phases I, II, and IV to be saline acid would be characterized for soluble aluminum.

The above-described characterization program would not preclude testing on a "complete analysis" basis on samples from master sites.

Soils & Water Laboratory Procedures and References

I. Soil Characterization

A. Physical Properties of Soils

1. Disturbed Hydraulic Conductivity is determined by the use of plastic tubes (Richards, et al., 1954, Diagnosis and Improvements of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 34b:112-113).

2. Settling Volume, Imoff Cones, (Series 510 Land Classification Techniques and Standards 517.5.7).

3. Particle Size Analyses are determined by pipeting and analysis (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 41:122-123).

4. Particle Density, (C.A. Black, et al., Methods of Soil Analysis Partz, Agronomy No. 9, American Society of Agronomy, 29:371-373), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 39:122).

5. Bulk Density, (C.A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy, 30-1:374-390), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 38:121-122).

6. Moisture Retention in Laboratory is determined by ceramic plates (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 29, 30 and 31:109-110).

7. Field Capacity - field determination.

8. Water holding capacity, determined by calculation, field capacity - wilting point x bulk density x 48 inches = water holding capacity per 48 inches of soil.

B. Soluble Cations and Anions

1. Carbonates and bicarbonates are determined with authomated Fisher titralyzer II by acid titration and chlorides are determined with automated Fisher titralyzer II, Specific Ion (Richards, et al., 1954, Diagnosos and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 82:145-146 and 84:146), (C.A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-3.4.1:945-947 and 62-3.5.1:947-948),

(M.J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition, for carbonate and bicarbonate only 102:52-56), (Bear, et al., Chemical of Soils, 1964), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory analysis for chloride only, p. 69).

2. Phosphorus soluble in sodium bicarbonate and Automated Ascorbic Acid (C.A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 73-4.4:1044-1049), (EPA Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 365.1:365.1-1-365.1-9).

3. Nitrate-Nitrite are determined by phenoldsulfonic acid and by Automated cadmium reduction (Richards-et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, Part 2, Agronomy No. 9, American Society of Agronomy 84.5.3:1216-1219) and (M.J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, 1971 Thirteenth Edition, 133:233-237) Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 353.2:353.2-1-353.2-7.

4. Sulfate are determined by Automated Methyl Thymol Blue and turbidimetric, (EPA Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020,375.2:375.2-1-375.2-4), (M.J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, 1971 Thirteenth Edition, 156C: 334-336).

5. Sodium, Potassium, Calcium and Mangesium are determined by Automated atomic absorption (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods of Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 66, 109, 133 and 143).

C. Trace Metals

1. Trace Metals are determined by atomic absorption with by flame or graphite furnace (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases", Book 5 - Laboratory Analysis, 50-157) and (M.J. Taras, et al., Standard Methods for the Examination of Water Wasteway, 1971 Thirteen Edition), Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, DTPA-TEA extraction for Cu, Fe, Mn, and Zn, University of Montana, Missoula, Montana.

D. Chemical Soil Characterization

1. pH reading of 1:5 Soil Suspension (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 21b:102) (C.A. Black, et al., Methods of Soil Analysis, Part 2 Agronomy No. 9, American Society of Agronomy 60-3.4:922-923) and (Bear, et al., Chemical of Soils, 1964).

2. Reading in $CaCl_2$ Solution (C.A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.5:923).

3. Saturation Extract taken from saturation soil paste using Bariod filter press and measuring soluble salts by use of electrode conductivity bridge (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 6, 2 and 3:84-88, 27:107 and 4:89-90), C.A. Black, et al., Methods of Soil Analysis, part 2, Agronomy No. 9, American Society of Agronomy 62-1:933-988) and (Bear, et al., Chemical of Soils, 1964).

4. Exchangeable Sodium and Potassium are extracted' by ammonium acetate solution. Cation-Exchange Capacity determined using Sodium Acetate as index ion and follow with Ammonium Acetate (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60,18:100-101 and 19:101) and (C.A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 72-3:1033, 72-3.2.1:1033-1034 and 57-1:891-895).

5. Exchangeable Sodium Percentage is determined by calculation relationship being $\frac{Na}{CEC} \times 100$ (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 20a:101).

6. Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22c:104).

7. Gypsum Requirement (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22d:104-105).

8. Boron was determined by extraction with hot water (C.A. Black, et al., Methods of Soil Analysis, Part 3 Agronomy No. 9, American Society of Agronomy 75-4:1062-1063 and 62-3.6 949-951).

9. Percent Oranic carbon is determined by Technicon Auto Analyzer II.

10. Total Carbonates express as % calcium carbonate, acid-neutralization, (C.A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy, 91-4:1387-1388), (Richards et al., 1954 Diagnosis and Improvement of Saline and Alkali Soils USDA Agriculture Handbook No. 60, 23c:105-106).

11. SAR (sodium absorption ratio) determined by calculation
$SAR = Na/\sqrt{Ca + Mg/2}$

Exhibit 3
(Includes the following 7 pages)

SUPPORTING DATA

Erosion evaluations (BLM Form 7310-12) correlating with USBR point site soil profile descriptions:

Point Site No. 7 - Sec. 8, T. 140 N., R. 98 W.
Point Site No. 8 - Sec. 10, T. 140 N., R. 98 W.
Point Site No. 7 - Sec. 10, T. 140 N., R. 98 W.
Point Site No. 5 - Sec. 20, T. 140 N., R. 98 W.
Point Site No. 7 - Sec. 22, T. 140 N., R. 98 W.
Point Site No. 9 - Sec. 14, T. 140 N., R. 99 W.
Point Site No. 7 - Sec. 26, T. 140 N., R. 99 W.

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Correlates with
USBR Point
Site No.7

By: T. Fiechtl | Date: 8/78

Location: Sec. 8, T.140N.,R.98W

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT*	No visual evidence of movement 0 1 2 (3)	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER*	Accumulating in place 0 1 2 (3)	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK*	If present, the distribution of fragments show no movement caused by wind or water 0 1 (2)	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING*	No visual evidence of pedestalling 0 1 2 (3)	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS*	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 (6)	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 (3)	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½' to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 (3)	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		23			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Correlates with USBR Point Site No. 8

By: T. Fiechtl | Date: 8/78

Location: Sec.10, T.140N.,R.98W

Treatment affecting the SSF:

DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT*	No visual evidence of movement 0 1 2 (3)	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER*	Accumulating in place 0 1 2 (3)	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
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RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 (6)	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 (3)	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		26			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Correlates with
USBR point
Site No. 7

By T. Fiechtl | Date 8/78

Location Sec. 10, T.140N., R.98W

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT*	No visual evidence of movement 0 1 2 **(3)**	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER*	Accumulating in place 0 1 2 **(3)**	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK*	If present, the distribution of fragments show no movement caused by wind or water 0 1 **(2)**	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
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FLOW PATTERNS*	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 **(6)**	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' **(4)** 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 **(3)**	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15
SITUATION	TOTAL	24			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Correlates with
USBR Point
Site No. 5

By: T. Fiechtl | Date: 8/78

Location: Sec.20, T.140N.,R.98W

Treatment affecting the SSF:

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 (3)	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 (3)	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water (3) 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 (3)	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 (6)	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 (6)	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 (3)	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		27			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Correlates with
USBR Point
Site No.7

By: T. Fiechtl | Date: 8/78

Location: Sec.22, T.140N.,R.98W

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 (3)	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER*	Accumulating in place 0 1 2 (3)	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
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RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals (7) 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes (0) 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15
SITUATION	TOTAL	21			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Correlates with
USBR Point
Site No.9

By	Date
T. Fiechtl	8/78

Location
Sec.14, T.140N.,R.99W

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT*	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 **(5)**	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
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SURFACE ROCK*	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water **(3)** 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
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FLOW PATTERNS*	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 **(5)** 6	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
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SITUATION	TOTAL				
		31			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Correlates with
USBR Point
Site No.7

By	Date
T.Fiechtl	8/78

Location
Sec.26,T.140N.,R.97W

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 (5)	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER*	Accumulating in place 0 1 2 3	May show slight movement 4 5 (6)	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
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SITUATION	TOTAL	39			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

GLOSSARY

Alluvium - A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited by a stream or other body of running water as a sorted or semisorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

Annual Plant (annuals) - A plant that completes its life cycle and dies in 1 year or less.

Aspect - The direction toward which a slope faces. Exposure.

Available Nutrient - The part of the supply of a plant nutrient in the soil that can be taken up by plants at rates and in amounts significant to plant growth.

Available Water - The part of the water in the soil that can be taken up by plants at rates significant to their growth. Usable: obtainable.

Bedrock - Any consolidated material (shale, sandstone, etc.) soft, weathered or hard that has remained in place and is relatively unchanged.

Broadcast Seeding - Scattering seed on the surface of the soil. Contrast with drill seeding which places the seed in rows in the soil.

Buffer - Substances in soil or water that act chemically to resist changes in reaction of pH.

Calcareous Soil - Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 normal hydrochloric acid.

Capillary Water - The water held in the "capillary" or small pores of a soil, usually with tension greater than 60 centimeters of the water. Much of this water is considered to be readily available to plants.

CFS, Cubic feet per second - measurement of water flow.

Channel Stabilization - Erosion prevention and stabilization of velocity distribution in a channel, using jetties, drops, revetments, vegetation, and other measures.

Clay (soils) - (1) A mineral soil separate consisting of particles less than 0.002 millimeter diameter. (2) A soil textural class. (3) (engineering) A fine-grained soil that has a high plasticity index in relation to the liquid limits.

Colluvium - A general term applied to loose, heterogeneous (mixed) deposits of soil material and/or rock fragments near the base of rather steep slopes. The deposits have accumulated through mass wasting (slides), soil creep, and local wash.

Compaction - The closing of the pore spaces among the particles of soil and rock, generally caused by running heavy equipment over the area, as in the process of leveling the overburden material of strip mine banks.

Companion Crop - (See Nurse Crop).

Conifer - A tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scale-like leaves and producing wood known commercially as "softwood."

Contour - An imaginary line connecting points of equal height above sea level as they follow the relief of the terrain.

Cool-Season Plant - A plant that makes its major growth during the cool portion of the year, primarily in the spring but in some localities in the winter.

Deciduous - Refers to a tree that sheds all its leaves every year at a certain season.

Deep Chiseling - Deep chiseling is a surface treatment that loosens compacted spoils. The process creates a series of parallel slots on the contour in the spoils surface which impedes water flows and markedly increases infiltration.

Density, Forage - The percent of ground surface which appears to be completely covered by vegetation when viewed directly from above.

Density, Stand - Density of stocking expressed in number of trees per acre.

Dissolved Solids - The difference between the total and suspended solids in water.

Disturbed Land - Land on which excavation has occurred or upon which overburden has been deposited, or both.

Dozer or Bulldozer - Tractor with a steel plate or blade mounted on the front end in such a manner that it can be used to cut into earth or other material and move said material primarily forward by pushing.

Ecology - The science that deals with the mutual relation of plants and animals to one another and to their environment.

Ecosystem - A total organic community in a defined area or time frame.

Effective Precipitation - That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone or to surface runoff.

Effluent - Any water flowing out of the ground or from an enclosure to the surface flow network.

Environment - All external conditions that may act upon an organism or soil to influence its development, including sunlight, temperature, moisture and other organisms.

Erodibility - The relative ease with which one soil erodes under specified conditions of slope as compared with other soils under the same conditions; this applies to both sheet and gully erosion.

Erosion - The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Detachment and movement of soil or rock fragments by water, wind or ice, or gravity.

Essential Element (plant nutrition) - A chemical element required for the normal growth of plants.

Evapotranspiration - A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

Excavation - The act of removing overburden material.

Fertilizer - Any natural or manufactured material added to the soil in order to supply one or more plant nutrients.

Fertilizer Grade - The guaranteed minimum analysis in whole numbers, in percent, of the major plant nutrient elements contained in a fertilizer material or in a mixed fertilizer. For example, a fertilizer with a grade of 20-10-5 contains 20 percent nitrogen (N), 10 percent available phosphoric acid (P_2O_5), and 5 percent water soluble potash (K_2O). Minor elements may also be included. Recent trends are to express the percentages in terms of the elemental fertilizer [nitrogen (N), phosphorous (P), and potassium (K)].

Fill - Depth to which material is to be placed (filled) to bring the surface to a predetermined grade. Also, the material itself.

Forage - Unharvested plant material which can be used as feed by domestic animals. Forage may be grazed or cut for hay.

Forest Land - Land bearing a stand of trees at any age or stature, including seedlings and of species attaining a minumum of 6 feet average height at maturity or land from which such a stand has been removed but on which no other use has been substituted. The term is commonly limited to land not in farms; forests on the farms are commonly called woodland or farm forests.

Germination - Sprouting; beginning of growth.

Gradation - A term used to describe the series of sizes into which a soil sample can be divided.

Grain Size - Physical size of soil particle, usually determined by either sieve or hydrometer analysis.

Ground Cover - Any living or dead vegetative material producing a protective mat on or just above the soil surface.

Ground Water - Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below water table. Also called plerotic water; phreatic water.

Growing Season - Determined by the Lowery-Johnson Method.

Gully Erosion - Removal of soil by running water with formation of deep channels that cannot be smoothed out completely by normal cultivation.

Hydroseeding - Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious - Prohibits fluid flow.

Infiltration - The downward entry of water into the land surface.

Intermittent Stream - A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and is dry for a large part of the year.

Land Classification - Classification of specific bodies of land according to their characteristics or to their capabilities for use. A use capability classification may be defined as one based on both physical and economic considerations according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic (mapping) expression to indicate those differences signigicant to men.

Land Use Planning - The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

Leaching - The removal of materials in solution by the passage of water through soil.

Leachate - Liquid that has percolated through a medium and has extracted dissolved or suspended materials from it.

Legume - A member of the legume or pulse family, leguminosae. One of the most important and widely distributed plant families. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches and kudzu. Practically all legumes are nitrogen-fixing plants.

Lime - From strictly chemical standpoint, refers to only one compound, calcium oxide (CaO); however, the term lime is commonly used in agriculture to include a great variety of materials which are usually composed of the oxide, hydroxide, or cabonate of calcium or of calcium and magnesium. The most commonly used forms of agricultural

lime are ground limestone, marl, and oyster shells (carbonates), hydrated lime (hydroxides), and burnt lime (oxides).

Quicklime - limestone + heat (calcined), CaO
Hydrated Line - quicklime + H_2O $Ca(OH)_2$
Slaked lime - same as hydrated but slaking equipment is used for adding water
Milk of lime - water mixture containing lime in solution + lime in suspension

Micro-Climate - A local climatic condition near the ground resulting from modification of relief, exposure, or cover.

Micro-Nutrients - Nutrients in only small, trace, or minute amounts.

Mined-Land - Land with new surface characteristics due to the removal of mineable commodity by surface mining methods and subsequent surface reclamation.

Mulch - A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion, and to modify soil temperature.

Natural Revegetation - Natural reestablishment of plants; propragation of new plants over an area by natural processes.

Natural seeding (Volunteer) - Natural distribution of seed over an area.

Neutralization - The process of adding an acid or alkaline material to water or soil to adjust its pH to a neutral position.

Neutral Soil - A soil in which the surface layer, at least from normal plow depth, is neither acid nor alkaline in reaction. For most practical purposes, soil with a pH ranging from 6.6 through 7.3.

Nitrogen Fixation - The conversion of atmospheric (free) nitrogen to nitrogen compounds. In soils the assimilation of free nitrogen from the air by soil organisms (making the nitrogen eventually available to plants). Nitrogen fixing organisms associated with plants such as the legumes are called symbiotic; those not definitely associated with plants are called nonsymbiotic.

Nurse Crop - A planting or seeding that is used to protect a tender species during its early life. A nurse crop is usually temporary and gives away to the permanent crop. Sometimes referred to as a companion crop.

Nutrients - Any element taken into a plant that is essential to its growth.

Overburden - All unconsolidated (soil, till, outwash, alluvium, etc.) and consolidated (shale, sanstone, etc.) materials which lie above the coal.

Percolation - Downward movement of water through soils.

Permeability - The measure of the capacity for transmitting a fluid through the substance. In this report the substance is overburden (soil and bedrock).

pH - The symbol or term refers to a scale commonly used to express the degrees of acidity or alkalinity. On this scale pH of 1 is the strongest acid, pH of 14 is the strongest alkali, pH of 7 is the point of neutrality at which there is neither acidity or alkalinity. pH is not a measure of the weight of acid or alkali contained in or available in a given volume (-Log of H+ activity).

Pollution - Environmental degradation resulting from man's activities or natural events.

Pond - A body of water of limited size either naturally or artificially confined and usually smaller than a lake.

Rain - (1) Heavy--Rain which is falling at the time of observation with an intensity in excess of 0.30 in. per hr (over 0.03 inch in 6 min). (2) Light--Rain which is falling at the time of observation with an intensity of between a trace and 0.10 in. per hr (0.01 inch in 6 min). (3) Moderate--Rain which is falling at the time of observation with an intensity of between 0.11 in. per hr (0.01+ inch in 6 min) and 0.30 in. per hr (0.03 inch in 6 min).

Range Land - The natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs.

Percolation Rate - Usually expressed as a velocity, at which water moves through saturated granular material. The term is also applied to quantity per unit or time of such movement, and has been used erroneously to designate infiltration rate or infiltration capacity.

Reclamation - The process of rehabilitating mined land to its former or other productive uses.

Reconstructed Profile - The result of selective placement of suitable overburden material on reshaped spoils.

Recreation Land - Land and water used, or usable primarily as sites for outdoor recreation facilities and activities.

Reforestation - The natural or artificial restocking of an area with forest trees.

Regrading - The movement of earth over a depression to change the shape of the land surface. A finer form of backfilling.

Rehabilitation - Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

Revegetation - The reestablishment of a vegetative cover following land disturbance.

Ripping - The act of breaking, with a tractor-drawn ripper or long angled steel tooth, compacted spoils or rock into pieces small enough to be economically excavated or moved by other equipment as a scraper or dozer.

Runoff - That portion of the rainfall that is not absorbed by the deep strata: is utilized by vegetation or lost by evaporation or may find its way into streams as surface flow.

Saline-Sodic Soil - A soil having a combination of a harmful quantity of soluble salts and either a high degree of sodicity or a high amount of exchangeable sodium, or both, so distributed in the soil profile that the growth of most crop plants is less than normal.

Saline Soil - A soil containing enough soluble salts to impair its productivity for plants but not containing an excess of exchangeable sodium.

Sandstone - A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Saturation - Completely filled; a condition reached by a material, whether it be in solid, gaseous, or liquid state, which holds another material within itself in a given state in an amount such that no more of such material can be held within it in the same state. The material is then said to be saturated or in a condition of saturation.

Sediment - Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Basin - A reservoir for the confinement and retention of silt, gravel, rock, or other debris from a sediment-producing area.

Seedbed - The soil prepared by natural or artificial means to promote the germination of seed and growth of seedlings.

Seep - A more or less poorly defined area where water oozes from the earth in small quantities.

Shale - Sedimentary or stratified rock structure generally formed by the consolidation of clay or clay-like material.

Silt - Small mineral soil grains, the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02-0.002 mm in the international system).

Soil (See Acid Soil and Alkaline Soil) - Surface layer of the earth, ranging in thickness from a few inches to several feet composed of finely divided rock debris mixed with decomposing vegetative and animal matter which is capable of supporting plant growth.

Soil Amendment - Any substance used to alter one or more of the many soil properties. These include soil conditioning agents, fertilizers, lime and manures, to name a few.

Soil Conserving Crops - Crops that prevent or retard erosion and maintain or replenish rather than deplete soil organic matter.

Soil Porosity - The degree to which the soil mass is permeated with pores or cavities. It is expressed as the percentage of the whole volume of the soil which is unoccupied by solid particles.

Soil Profile - A vertical section of the soil through all its horizons and extending into the parent material.

Soil Structure - The combination or arrangement of primary soil particles into secondary particles, units, or peds.

Solum - The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in natural soils includes the A and B horizons. Usually the characteristics of the material in these horizons are quite unlike those of the underlying parent material. The living roots and other plant life and animal life characteristic of the soil are largely confined to the solum.

Spoil - The overburden or non-coal material removed in gaining access to the coal or mineral material in surface mining.

Spoil Bank (Spoil Pile) - Area created by the deposited soil or overburden material prior to backfilling. Also called cast overburden.

Stratified - Composed of, or arranged in, strata or layers, as stratified alluvium. The term is applied to geological materials. Those layers in soils that are produced by the processes of soil formation are called horizons, while those inherited from parent material are called strata.

Strip - To mine a deposit by first taking off the overlying burden.

Stripping - The removal of earth or non-ore rock materials as required to gain access to the ore or mineral materials wanted. The process of removing overburden or waste material in a surface mining operation.

Subsoil - The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as "subsoil."

Substratum - Alluvial, colluvial, or bedrock material that underlies the soil profile.

Surface Mining - Refers to a procedure of mining which entails the complete removal of all material from over the resource to be mined in a series of rows or strips; also referred to as "strip mining."

Surface Soil - The upper part of arable soils commonly stirred by tillage implements or an equivalent depth (5 to 8 minches) in non-arable soils.

Suspended Soilids - Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Terrace - Sloping ground cut into a succession of benches and steep inclines for purposes of cultivation or to control surface runoff and minimize soil erosion.

Terraced Slope - A slope that is intersected by one or more terraces.

Texture (Soils) - Refers to the fineness or coarseness of a soil. Specifically, it refers to the relative proportions of the various soil separates (sand, silt, clay) in a given soil.

Topdressing Material - Material that is well suited for plant media. Desired characteristics include: fertile, good tilth, permeable, contains organic matter, nonsaline, nonsodic and has water stable aggregates.

Tilth - The physical condition of a soil in respect to its fitness for the growth of a specified plant.

Topography - The shape of the ground surface, such as hills, mountains, or plains. Steep topography indicates steep slopes or hilly land; flat topography indicates flat land with minor undulations and gentle slopes.

Toxic Spoil (See also Acid Spoil) - Includes acid spoil with pH below 4.0. Also refers to spoil containing excessive levels of exhangeable sodium or trace elements (i.e., selenium, lead, etc.).

Transpiration - The normal loss of water vapor to the atmosphere from plants.

Unconsolidated (soil material) - Soil material in a form of loose aggregation.

Vegetation - General term including grasses, legumes, shrubs, and trees naturally occurring and planted intentionally.

Vegetative Cover - The entire vegetative canopy on an area.

Volunteer - Springing up spontaneously or without being planted; a volunteer plant.

Weathering - The group of processes, such as chemical action of air and rainwater and of plants and bacteria and the mechanical action of changes in temperature, whereby rocks, on exposure to the weather, change in character, decay, and finally crumble.

Wildlife - Undomesticated vertebrate animals, except fish, considered collectively.